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Discover the wonders of the universe

"The problem with Mars is that it's very much a frozen world now"

Charles Cockell, professor of astrobiology, Edinburgh University

We've been obsessing about finding life on Mars for over a century now. In the past this has led to wild conclusions that today would drop jaws among members of the public and in scientific circles alike. Schiaparelli's discovery of supposed extraterrestrial Martian canals got everyone hopping around with excitement in the late 19th century, but that wasn't even to be the pinnacle of sensational Red Planet misconceptions to come.

Nearly 50 years later the radio adaptation of *War of the Worlds* used a news-bulletin format, which had some listeners convinced that Martian tripods were really attacking Earth. This caused a furore that director Orson Welles couldn't have predicted. To call the public reaction to this broadcast hysterical would be an overstatement, but the rumour mill churned and the media ultimately responded with pitchforks and burning torches. Newspapers branded the CBS network that aired *War Of The Worlds* as irresponsible, using this opportunity to make the broadcast a scapegoat in their war against the new and rival medium of radio.

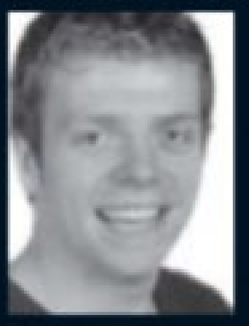
With daily, hourly and even more-frequent progress updates on a multitude of Mars missions available at our fingertips, we've little opportunity to allow our imaginations to carry us away today. For the mainstream scientific community this is an absolute, as their professionalism requires them to pore over minutiae, submitting any conclusion to the scrutiny of their peers before being released into the wider world.

However we're close, very close to what will either way be a watershed moment in space exploration and an exciting time when it happens.

Ben Biggs
Editor

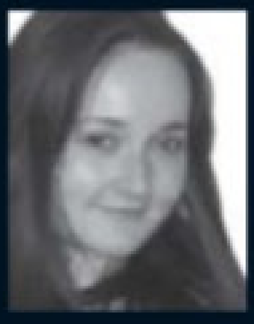
Crew roster

Jonathan O'Callaghan



■ This issue Jonny's found one of our favourite Amazing Images ever… check it out and the rest starting on page six

Gemma Lavender

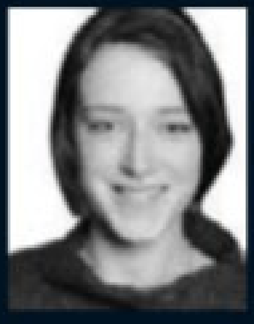


■ Gemma has brought the universe to her this issue, with a full guide to backyard astronomy

Shanna Freeman

■ The Virgo supercluster is Shanna's particular giant oyster of choice in the All About feature

Laura Mears



■ A healthy obsession with the Red Planet made Laura the perfect writer for our cover article

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LAUNCH PAD

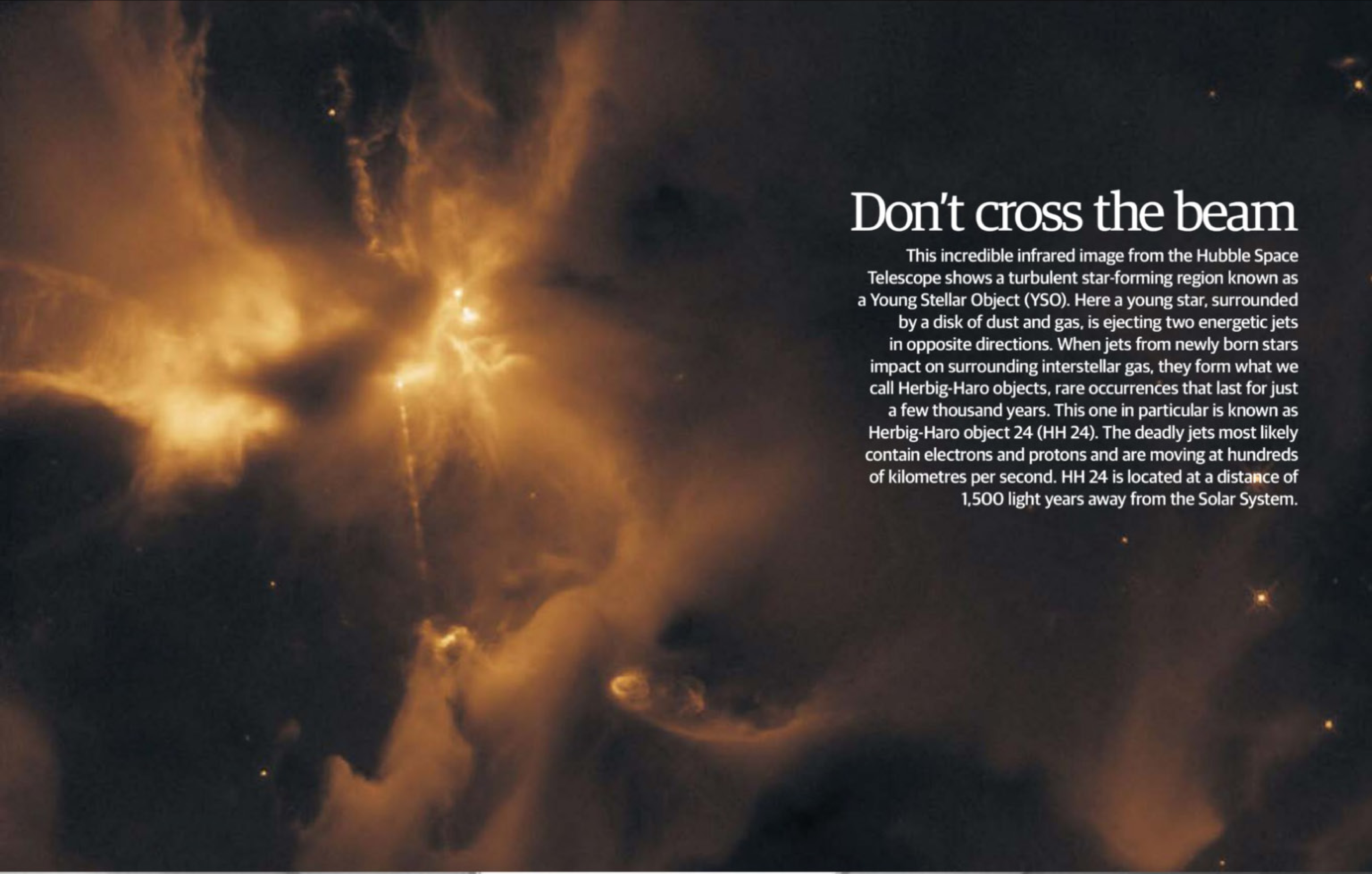
YOUR FIRST CONTACT WITH THE UNIVERSE

The Crab nebula's argon surprise

This composite image of the famous Crab nebula uses data from ESA's Herschel Space Observatory (red) and NASA's Hubble Space Telescope (blue) to highlight some of its defining features. Most notably, the image provides the first evidence for a noble-gas-based molecule, in this instance argon, in space. A compound of argon was found in the famous supernova remnant, believed to be a product of the original explosion itself, although the survival of argon in the harsh environment of such a remnant came as a surprise to astronomers.

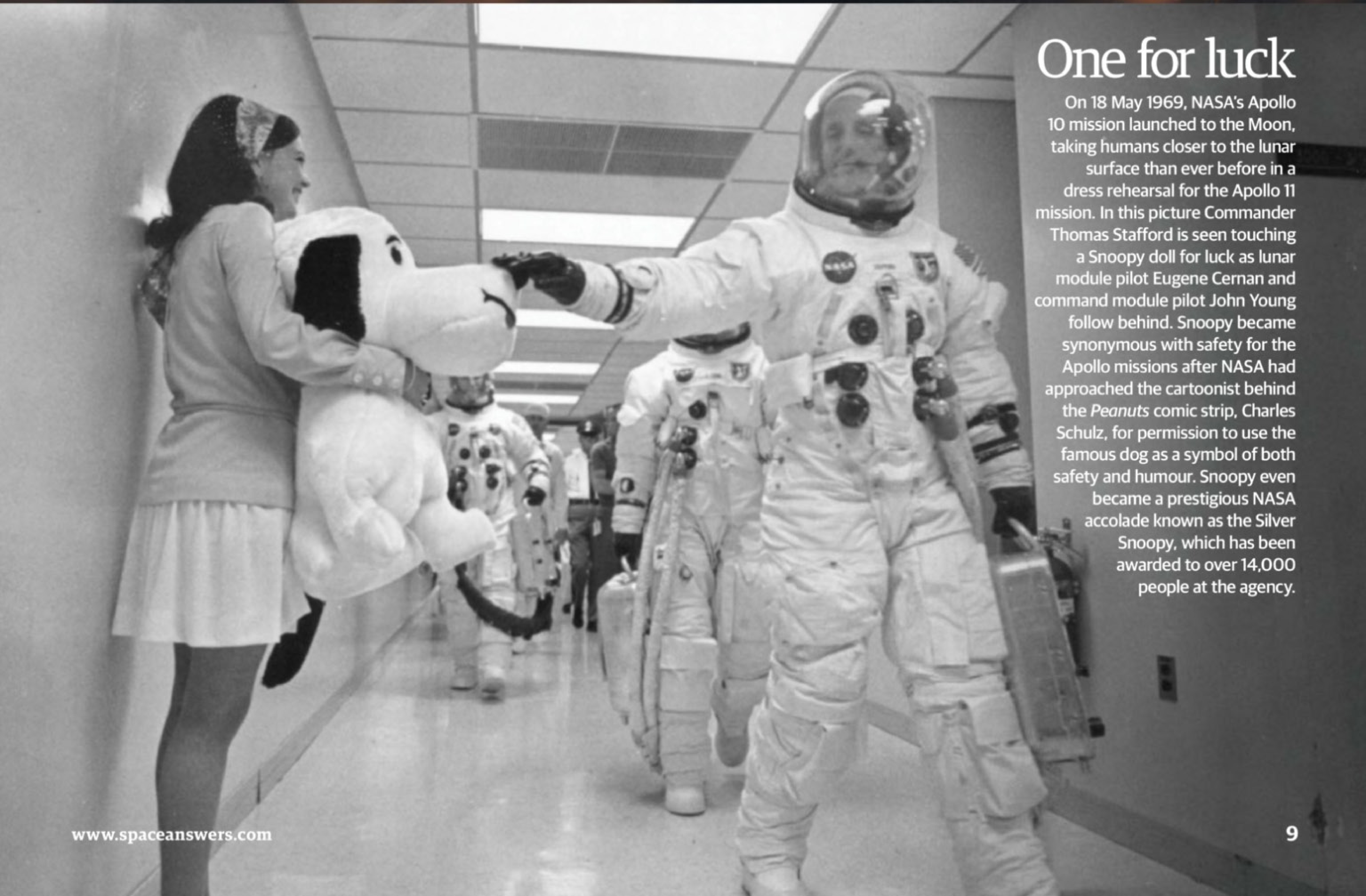
Soyuz survival

In this image German ESA astronaut Alexander Gerst is seen training at Star City, Russia on 13 February 2014. In this particular exercise he is preparing for a scenario where the Soyuz has had to perform an emergency landing in water, when he must be able to survive long enough to be airlifted to safety by rescue helicopters. Survival training of this sort is an important part of Soyuz mission preparation and the astronauts must be ready for a host of different scenarios in case of a problem during re-entry and landing. Gerst is a flight engineer for Expedition 40/41, and he will be launching to the ISS in May 2014.



Don't cross the beam

This incredible infrared image from the Hubble Space Telescope shows a turbulent star-forming region known as a Young Stellar Object (YSO). Here a young star, surrounded by a disk of dust and gas, is ejecting two energetic jets in opposite directions. When jets from newly born stars impact on surrounding interstellar gas, they form what we call Herbig-Haro objects, rare occurrences that last for just a few thousand years. This one in particular is known as Herbig-Haro object 24 (HH 24). The deadly jets most likely contain electrons and protons and are moving at hundreds of kilometres per second. HH 24 is located at a distance of 1,500 light years away from the Solar System.



One for luck

On 18 May 1969, NASA's Apollo 10 mission launched to the Moon, taking humans closer to the lunar surface than ever before in a dress rehearsal for the Apollo 11 mission. In this picture Commander Thomas Stafford is seen touching a Snoopy doll for luck as lunar module pilot Eugene Cernan and command module pilot John Young follow behind. Snoopy became synonymous with safety for the Apollo missions after NASA had approached the cartoonist behind the *Peanuts* comic strip, Charles Schulz, for permission to use the famous dog as a symbol of both safety and humour. Snoopy even became a prestigious NASA accolade known as the Silver Snoopy, which has been awarded to over 14,000 people at the agency.

Greece lightning

On 3 March 2014, a NASA-funded sounding rocket was launched into an aurora from the Poker Flat Research Range in Alaska, USA. Known as the Ground-to-Rocket Electrodynamics – Electron Correlative Experiment (GREECE), this mission passed through the aurora above the village of Venetie to study a phenomenon known as aurora curls. The experiment will help us understand how energy and particles from the Sun interacts with Earth's magnetosphere to create the charged, heated gas known as plasma where auroras form. A sounding rocket is one that travels on a parabolic trajectory and carries scientific instruments on a brief journey into space. Although the time in space will vary from just 5 to 20 minutes, it's enough to perform important experiments such as this in regions inaccessible to orbiting satellites or high-altitude aircraft.

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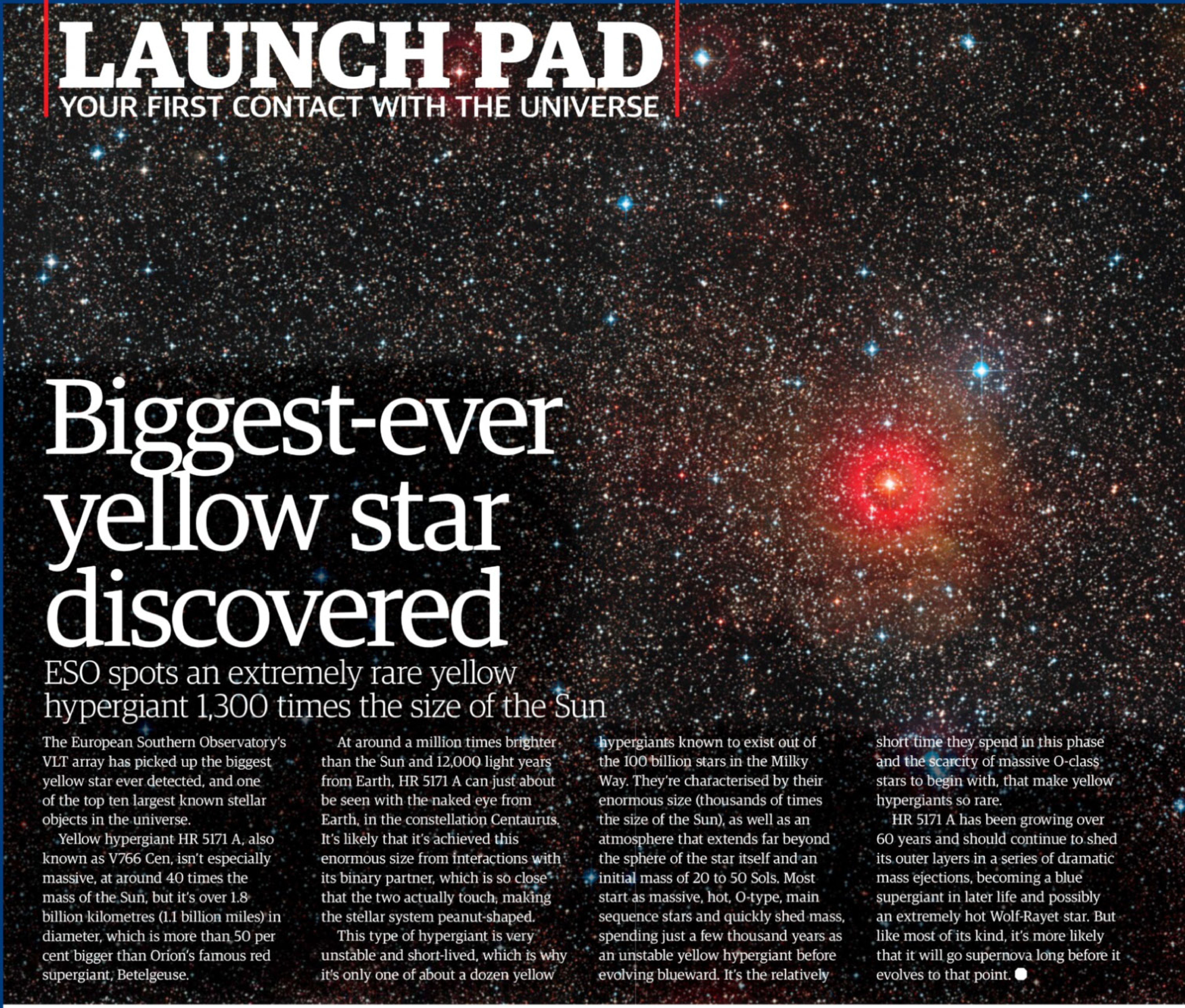


Biggest-ever yellow star discovered

ESO spots an extremely rare yellow hypergiant 1,300 times the size of the Sun

The European Southern Observatory's VLT array has picked up the biggest yellow star ever detected, and one of the top ten largest known stellar objects in the universe.

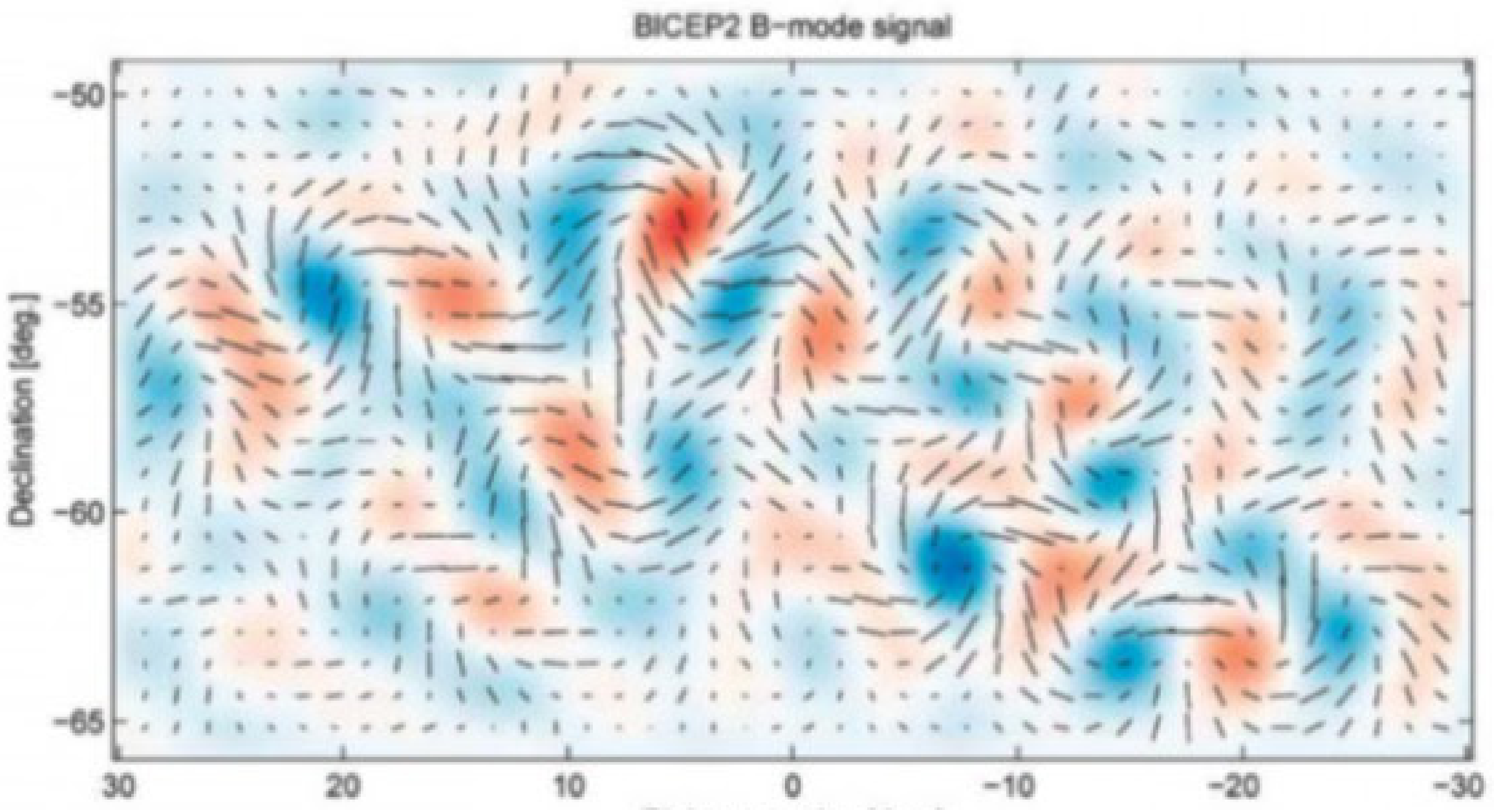
Yellow hypergiant HR 5171 A, also known as V766 Cen, isn't especially massive, at around 40 times the mass of the Sun, but it's over 1.8 billion kilometres (1.1 billion miles) in diameter, which is more than 50 per cent bigger than Orion's famous red supergiant, Betelgeuse.

At around a million times brighter than the Sun and 12,000 light years from Earth, HR 5171 A can just about be seen with the naked eye from Earth, in the constellation Centaurus. It's likely that it's achieved this enormous size from interactions with its binary partner, which is so close that the two actually touch, making the stellar system peanut-shaped.

This type of hypergiant is very unstable and short-lived, which is why it's only one of about a dozen yellow hypergiants known to exist out of the 100 billion stars in the Milky Way. They're characterised by their enormous size (thousands of times the size of the Sun), as well as an atmosphere that extends far beyond the sphere of the star itself and an initial mass of 20 to 50 Sols. Most start as massive, hot, O-type, main sequence stars and quickly shed mass, spending just a few thousand years as an unstable yellow hypergiant before evolving blueward. It's the relatively short time they spend in this phase and the scarcity of massive O-class stars to begin with, that make yellow hypergiants so rare.

HR 5171 A has been growing over 60 years and should continue to shed its outer layers in a series of dramatic mass ejections, becoming a blue supergiant in later life and possibly an extremely hot Wolf-Rayet star. But like most of its kind, it's more likely that it will go supernova long before it evolves to that point. ●

Direct evidence of cosmic inflation acquired



The curling pattern of the B-mode signal imaged by the BICEP2 telescope from the South Pole

A Big Bang signal is detected and a Nobel Prize nomination is under discussion

Scientists measuring the cosmic microwave background from the South Pole have announced the discovery of direct evidence for cosmic inflation, the event that is thought to have been initiated by the Big Bang. The BICEP2 (Background Imaging of Cosmic Extragalactic Polarization) telescope collaboration had been gathering data on the B-mode polarisation of the cosmic microwave background, when scientists picked up what has been described as the smoking gun for cosmic inflation.

"This has been like looking for a needle in a haystack," said Clem Pryke of the University of Minnesota, co-leader of the project. "Instead, we found a crowbar. This work offers new insights into some of our most basic questions. Why do we exist? How did the universe begin?"

The BICEP2 team had been hunting for the distinctive curling pattern of the B-mode polarisation in ancient light from nearly 14 billion years ago, when they happened upon a signal

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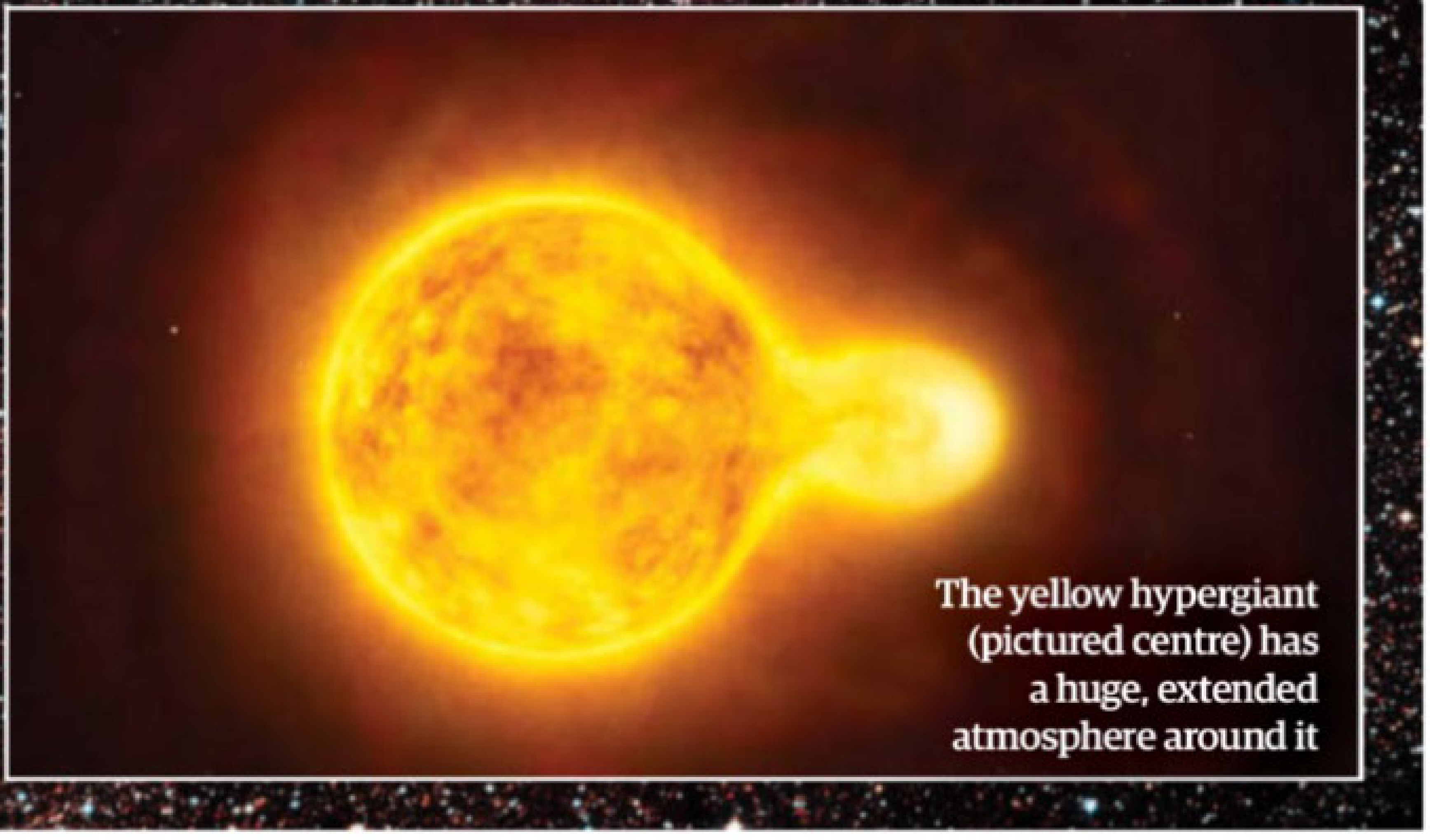
HR 5171 A has a smaller binary and is a million times brighter than the Sun

> "50 per cent bigger than Orion's famous red supergiant, Betelgeuse"



The yellow hypergiant (pictured centre) has a huge, extended atmosphere around it

much stronger than expected. It took three years of error-checking before scientists could confirm that this was a signal originating from the very dawn of time.

The B-mode polarisation signal occurred during cosmic inflation, when the cosmic microwave background, under the influence of gravitational waves, was scattered by electrons and became polarised. This theory, which states that the universe expanded 100 trillion, trillion times in size in a fraction of a second, dates back to a prediction made in 1996 by several theoretical physicists. One of these physicists, UC Berkeley professor of physics and astronomy Uros Seljak has described the discovery as "in general, a major breakthrough in the field of cosmology and probably a Nobel Prize-level discovery." ■

> "This work offers new insights into some of our most basic questions. Why do we exist? How did the universe begin?"

Introducing the grizzly bear: one of the most ferocious animals in nature

World Of Animals issue five on sale now

From the slovenly sloths of the Amazon rainforest to the predatory polar bears of the Arctic Circle, **World of Animals** is a new monthly magazine from the makers of **How It Works** and **All About History** that takes a unique look at wonderful wildlife from all over the globe.

With breathtaking photography, captivating stories and stunning illustrations, each issue offers the safari of a lifetime that takes you on a fact-filled tour of the planet's favourite wildlife, exploring the habitats, behaviour and societies of all Earth's creatures, great, small and everything in between.

On sale now, issue five will take you to the wild country of continental North America, where you can discover the incredible story of apex predator the grizzly bear and its prey. Read about the wily red fox, deadly saltwater crocodile, the elusive snow leopard and more – plus 50 animal myths are busted.

World of Animals magazine can be found alongside digital editions for iOS and Android available from **greatdigitalmags.com** and is accompanied by a brand-new companion website: **animalanswers.co.uk**. Be sure to connect on Twitter @WorldAnimalsMag and **facebook.com/worldofanimalsmag**. ■

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Does dark matter cause extinctions?

A recent theoretical model proposes that a thin disk of dark matter running through the galaxy could have wiped out the dinosaurs. Every 35 million years, objects in the Oort cloud are displaced, causing comet storms.

Brown dwarf weather detected

The European Southern Observatory's VLT has helped to create the first-ever weather map of the nearest brown dwarf star to Earth. These objects are somewhere between gas giant planets and small dwarf stars.

Mercury is shrinking

The Sun's closest planet, Mercury, has been shown to be shrinking by NASA's Messenger spacecraft. As it has cooled over billions of years, the liquid iron core has shrunk, contracting the crust by as much as seven kilometres (4.3 miles) and wrinkling it in the process.

Cosmic dust survey completed

The ESA's Herschel Space Observatory has completed its survey of cosmic dust in local galaxies. This dust is a key component in creating the stars and planets and the data from the survey will help scientists understand how galaxies evolve.

NASA announces twin astronaut experiment

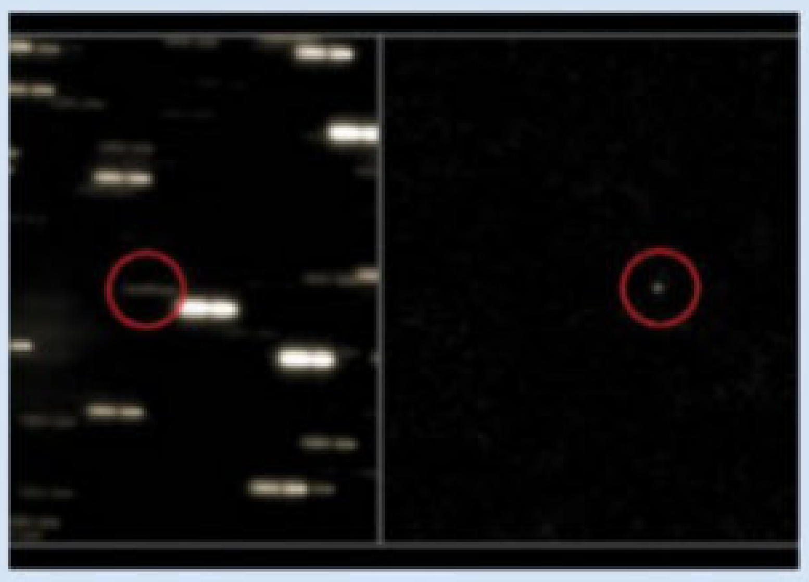
Identical twins are used to test how spaceflight affects DNA

The Kelly brothers are identical twins and will take part in the NASA experiment

NASA has chosen ten investigations to be conducted on identical twin astronauts Mark and Scott Kelly. Among the well-established physiological, microbiological and behavioural health studies, the study will investigate how spaceflight affects the blueprint of human life, DNA and RNA. NASA will look into the way radiation, microgravity and confinement aboard the International Space Station can change proteins and metabolites in the body. Studies will also be conducted into how genes in cells can be turned on and off.

One of the Kelly brothers, Mark, is retired and will remain on Earth while Scott Kelly will spend a whole year in low-Earth orbit on board the ISS, starting in 2015.

Twins make good subjects for how spaceflight affects the body because, although most humans are 99.5 per cent genetically the same, certain twins are nearly 100 per cent identical. Spaceflight can affect astronauts in many ways, so by studying the twins in controlled conditions, the variables can be reduced and more-accurate data can be obtained. ■


The VLT's image of the comet (left) and with star trails removed (right)

Rosetta's target appears from behind the Sun

Comet 67P/Churyumov-Gerasimenko has finally been spotted, emerging from the other side of the Sun from Earth's vantage point. It's been hiding since early October last year and the European Southern Observatory imaged it using its VLT (Very Large Telescope) in late February. The four-kilometre (2.5-mile) block of ice and dust has brightened much quicker than expected in the time it has spent out of sight and is now 50 per cent brighter than it was before. This suggests that it has started to evaporate as it moves nearer to the Sun, although it's yet to make its closest approach, at a distance of 185 million kilometres (115 million miles) in August 2015.

The Rosetta spacecraft was launched by the ESA in March 2004, with a mission to conduct a detailed study of the comet 67P/Churyumov-Gerasimenko, which has a current orbital period of 6.45 years. Rosetta will enter a slow orbit around the comet in May, before releasing the Philae lander, which will attach to the nucleus and take samples in November. ■

Asteroid-hunting competition launched

NASA and Planetary Resources offer cash prizes to citizen scientists

NASA is offering $35,000 (£21,000) in rewards to participants of its Asteroid Data Hunter challenge. The competition, which has been launched in partnership with space mining company Planetary Resources, offers programmers the opportunity to contribute to NASA's Asteroid Grand Challenge by coding improved algorithms that help the agency identify asteroids.

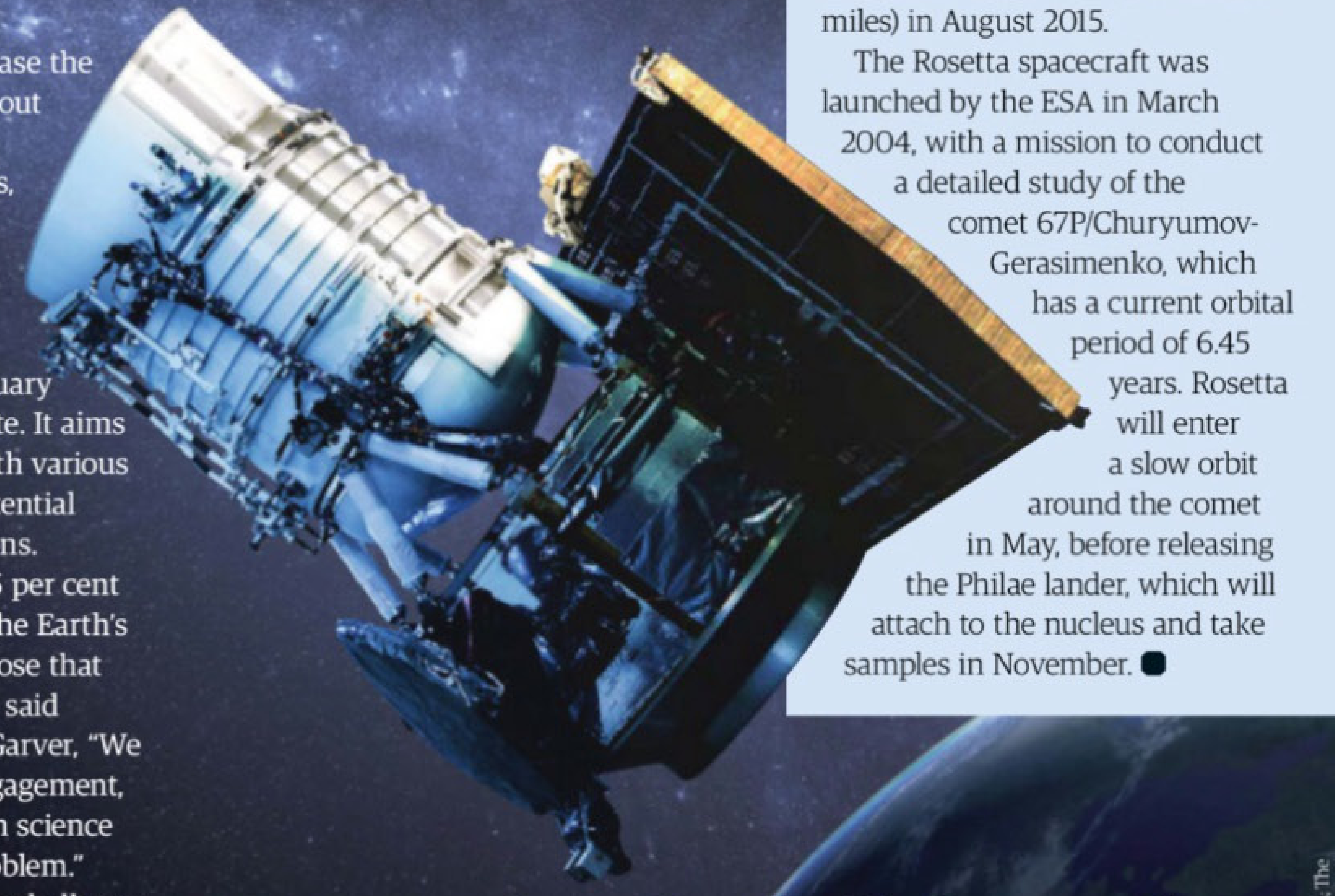
Comprised of two phases with ten separate contests, the competition challenges coders to create content and crush bugs in programs that enable NASA's automated systems to seek out moving objects in the night sky, sorting unidentified asteroids from everything else in space.

"Current asteroid-detection initiatives are only tracking one per cent of the estimated objects that orbit the Sun," said Planetary Resources president Chris Lewicki. "We are excited to partner with NASA in this contest to help increase the quantity and knowledge about asteroids that are potential threats, human destinations, or resource-rich."

NASA's Asteroid Grand Challenge was launched in June last year after the wake-up call that was February 2013's Chelyabinsk meteorite. It aims to leverage partnerships with various organisations to find all potential threats to human populations.

"While we have found 95 per cent of the large asteroids near the Earth's orbit, we need to find all those that might be a threat to Earth," said deputy administrator Lori Garver, "We will also harness public engagement, open innovation and citizen science to help solve this global problem."

The Asteroid Data Hunter challenge went live on 17 March and will run over the following five months until it closes in August. ■


The NEOWISE (Wide-field Infrared Survey Explorer) space telescope, also on a dedicated hunt for asteroids and comets

"We need to find all those that might be a threat to Earth"

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In the style of the most action-packed James Bond movies, this novel launches you into a suspenseful story of international space intrigue and never lets up the pace.

Francis French, author,
In the Shadow of the Moon

International conspiracy hurls secret agent Peter Novak through another space-age thriller as he goes behind the scenes and back into orbit to thwart another Chinese plot.

Scott Gunnerson,
Florida Today

WHAT IF THE MOST EXPENSIVE AND AMBITIOUS STRUCTURE EVER ASSEMBLED, THE INTERNATIONAL SPACE STATION, WAS THREATENED?

"Riveting... couldn't put it down!"

Charlie Duke
Apollo 16 Moonwalker

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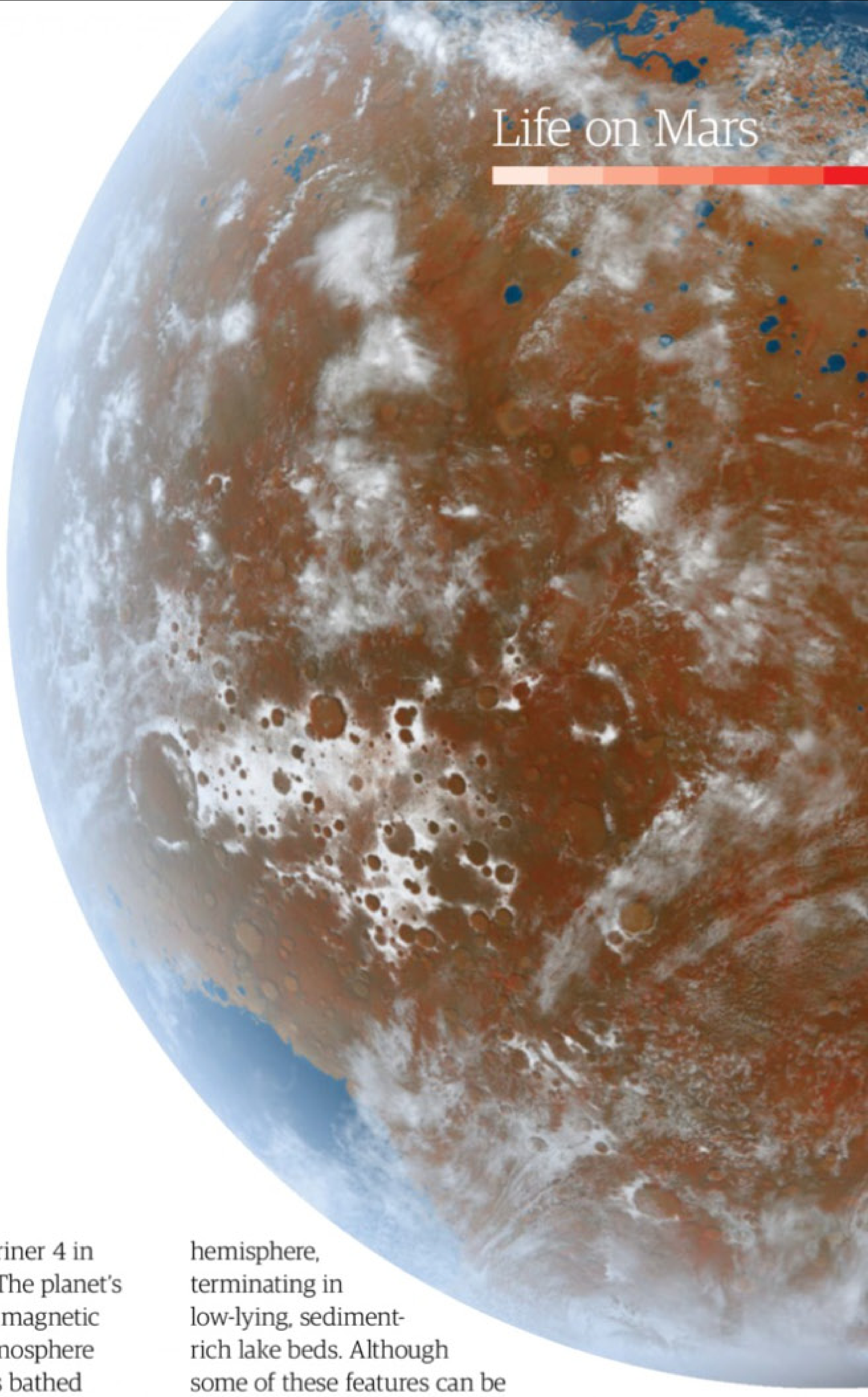
LIFE ON MARS

The Red Planet was once home to ancient lakes and rivers, but could these bodies of water have given rise to extraterrestrial life?

Written by Laura Mears



- Liquid water once flowed on the surface
- A thicker, protective, ancient atmosphere
- Evidence of a past habitable world

The first images of Mars returned by Mariner 4 in 1965 revealed a dry, desolate wasteland. The planet's once molten iron core has cooled and its magnetic field has dissipated, enabling the thin atmosphere to be ravaged by solar wind. Its surface is bathed in DNA-damaging, ultraviolet radiation and its temperature varies from lows of -143, to highs of 35 degrees Celsius (-225 to 95 degrees Fahrenheit). At first glance, the Red Planet seems like an unlikely candidate for a habitable planet, but Mars wasn't always this bleak.

The Red Planet is just half the size of Earth and farther from the Sun, but four billion years ago the two planets were surprisingly similar. Both were volcanically active and each had a molten iron core. Mars still had its magnetic field at this time and its atmosphere was thicker than it is today, providing enough atmospheric pressure for liquid water to exist on the surface.

At this time, the inner Solar System was being assaulted by the late heavy bombardment (LHB). Over the course of 300 million years, meteorites jettisoned towards the Sun by the enormous gravity of the gas giant Jupiter pummelled the four innermost planets. The meteorites, formed in the cold outer Solar System, were rich in volatiles including ice and are thought to have been the main supplier of the water that filled the Earth's oceans. They could also have supplied liquid water to Mars. The scars left by the late heavy bombardment can be seen across the surface of the Red Planet as vast craters in the southern hemisphere.

Some of the first evidence that there was once liquid water on the surface of Mars was captured by the Viking orbiters and later reinforced by maps made of the surface by the Mars Global Surveyor. Extensive networks of valleys can be seen extending down the sides of mountains and craters in the southern hemisphere, terminating in low-lying, sediment-rich lake beds. Although some of these features can be explained by lava flows, carbon dioxide erosion or wind storms, many scientists are in agreement that the pattern of the channels matches the way that water would be expected to behave, flowing for thousands of kilometres downstream.

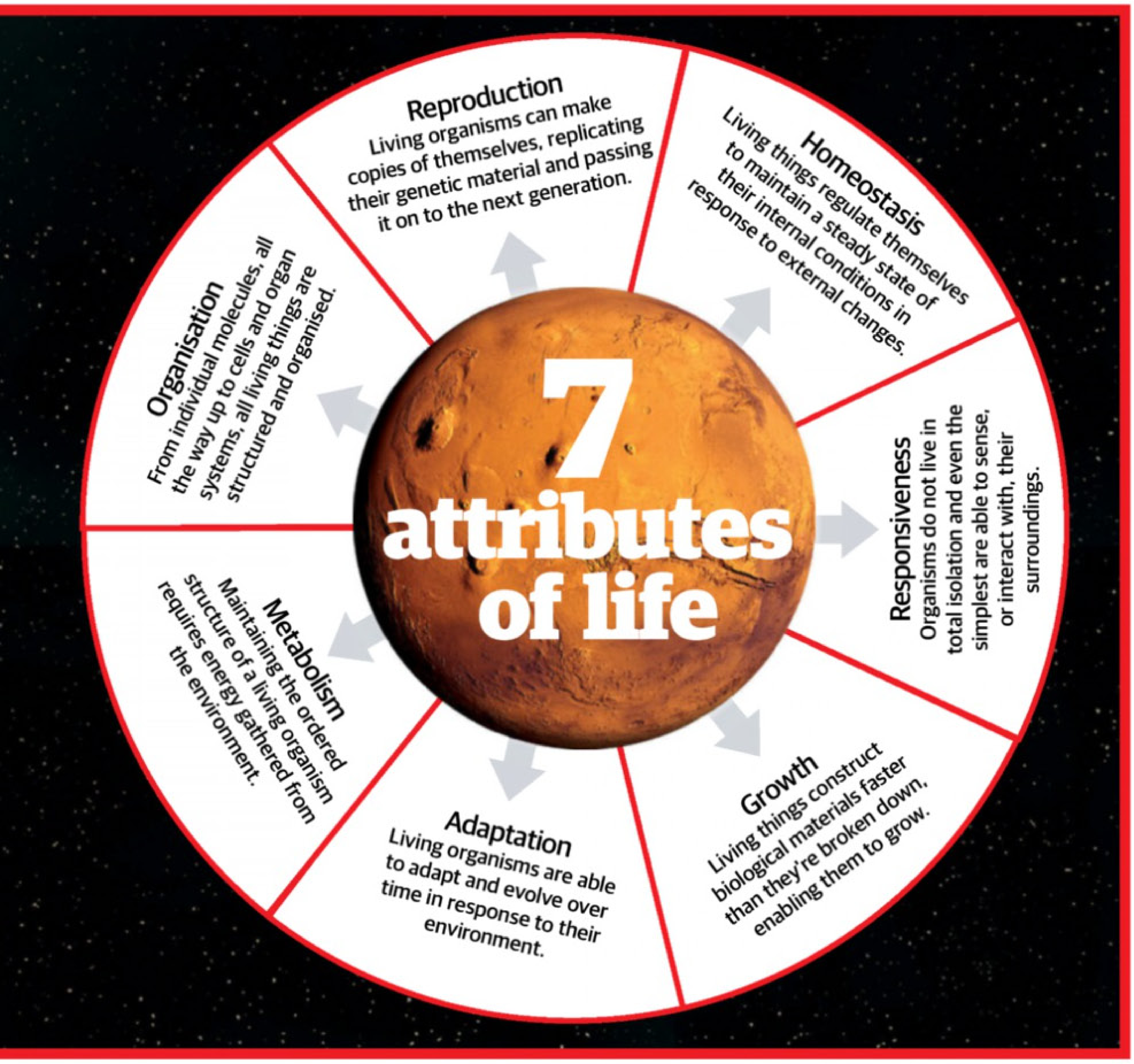
It's even possible that Mars once had an ocean. Early in Mars' history, the top of the planet was crushed either by a large impact, or by convection beneath the crust, leaving the northern hemisphere 30 kilometres (18.6 miles) thinner than the southern, and six kilometres (3.7 miles) lower in elevation. The patterns left by water on the surface of the planet show that it pooled in low-lying areas and if liquid water had been present in sufficient volumes, it could have flooded the top third of the planet. Unfortunately, the northern lowlands have been substantially remodelled by lava flow and evidence of any water in the area at this time has been buried.

So, what makes water so interesting? Not only is all life on Earth based on this colourless, odourless liquid, it's probable that all forms of life in the universe require a similar liquid solvent. In order to form a living organism capable of performing the complex functions associated with life, biological molecules must be relatively large and able to organise into complex structures. Large molecules in their pure form tend to exist in a solid state and react much too slowly to sustain life, so they must be dissolved in something that enables them to collide. Water appears to be uniquely suited to this task.

The molecules that make up water are small and polar, with a slight charge at either end. This makes it extremely efficient at dissolving not only

NASA astrobiologist Jason Dworkin holds a layered sedimentary Earth rock, an analogous of which on Mars could suggest primitive life was once on the Red Planet

> "The Curiosity rover has uncovered tangible geological evidence of surface water on ancient Mars"



7 attributes of life

Reproduction
Living organisms can make copies of themselves, replicating their genetic material and passing it on to the next generation.

Homeostasis
Living things regulate themselves to maintain a steady state of their internal conditions in response to external changes.

Responsiveness
Organisms do not live in total isolation and even the simplest are able to sense, or interact with, their surroundings.

Growth
Living things construct biological materials faster than they're broken down, enabling them to grow.

Adaptation
Living organisms are able to adapt and evolve over time in response to their environment.

Metabolism
Maintaining the ordered structure of a living organism requires energy gathered from the environment.

Organisation
From individual molecules, all the way up to cells and organ systems, all living things are structured and organised.

polar organic molecules, but also ions, bringing the building blocks of life together. Water also has many other unusual properties suited to supporting life. It's able to absorb huge amounts of heat before increasing in temperature, making it ideal for maintaining a stable environment. The fact it can exist in all three states - solid, liquid and gas - over a narrow temperature range is also useful for supporting life. Not only that, but it expands as it freezes, floating on the surface of liquid water and acting as an insulator, preventing lakes and oceans turning into solid blocks of ice.

One of the most compelling ideas for the location of the origin of life on Earth is the "warm little pond" described by Charles Darwin in his letter to Joseph Hooker. His idea was that a mixture of simple chemicals, dissolved in the warm water of a protected pond, might generate life when exposed to the high energy of a lightning strike. In 1953 this hypothesis was put to the test in the Miller-Urey experiment. Using a combination of water, methane, ammonia, hydrogen and a spark to simulate lightning, many biological amino acids were produced - the building blocks of protein. The volcanic gasses present in the early atmosphere on Earth were also capable of producing biological molecules.

Recently the Curiosity rover has uncovered tangible geological evidence of surface water on ancient Mars and a potential extraterrestrial location for Darwin's warm little pond. Inside the basin of the Gale impact crater, Curiosity has mapped the outline of an ancient lake and has identified streambed pebbles with the familiar smooth surface of a stone found at the beach, weathered after years of tumbling over other rocks beneath the water. Curiosity also found several biologically important elements in the surrounding soil, including nitrogen, oxygen, phosphorous and sulphur. Geological evidence suggests that the lake was freshwater, and neither too acidic nor too alkaline; conditions matching those required to support many of Earth's microbial life forms. Curiosity project scientist John Grotzinger has described the ancient freshwater lake as being "almost Earth-like"; it is thought to have existed for tens if not hundreds of thousands of years, providing a potential home for early Martian life.

The thin atmosphere that encases modern-day Mars is composed of around 95 per cent carbon dioxide, with small amounts of argon, nitrogen, oxygen and carbon monoxide. These gasses in combination contain no hydrogen and are unlikely to produce biological molecules. However, during the volcanic past of the planet, the atmosphere may have been very different, containing methane, sulphur dioxide and hydrogen sulphide, potentially providing pools of surface water with a source of biologically relevant elements.

An alternative location for the beginnings of life on Mars could have been hydrothermal vents below the water. On Earth, these volcanic hotspots reach temperatures in excess of the boiling point of water, but they're rich in minerals and home to chemosynthetic bacteria and archaea, some of Earth's most primitive life forms. Known as chemoautotrophs, these single-celled organisms use inorganic energy sources, such as hydrogen sulphide or ferrous iron, to synthesise biological compounds

Surviving on Mars

Protection from radiation
Mars has no ozone layer to provide shielding against ultraviolet light. This damages the structure of DNA, so any life is likely to be under the ground.

Some heat
If the temperature is too high, matter cannot stay together long enough to form living organisms. If it's too low, chemical reactions happen too slowly to sustain life.

Oxygen
As the second most electronegative element found in the periodic table, oxygen is highly reactive and is used by biological organisms to liberate energy.

Liquid water
Biological molecules are large and in solid form would be slow to react, so in order to sustain life they must be dissolved.

from carbon dioxide. These organisms survive entirely on chemical energy and live completely independently of the Sun, enabling them to survive far below the surface of the ocean.

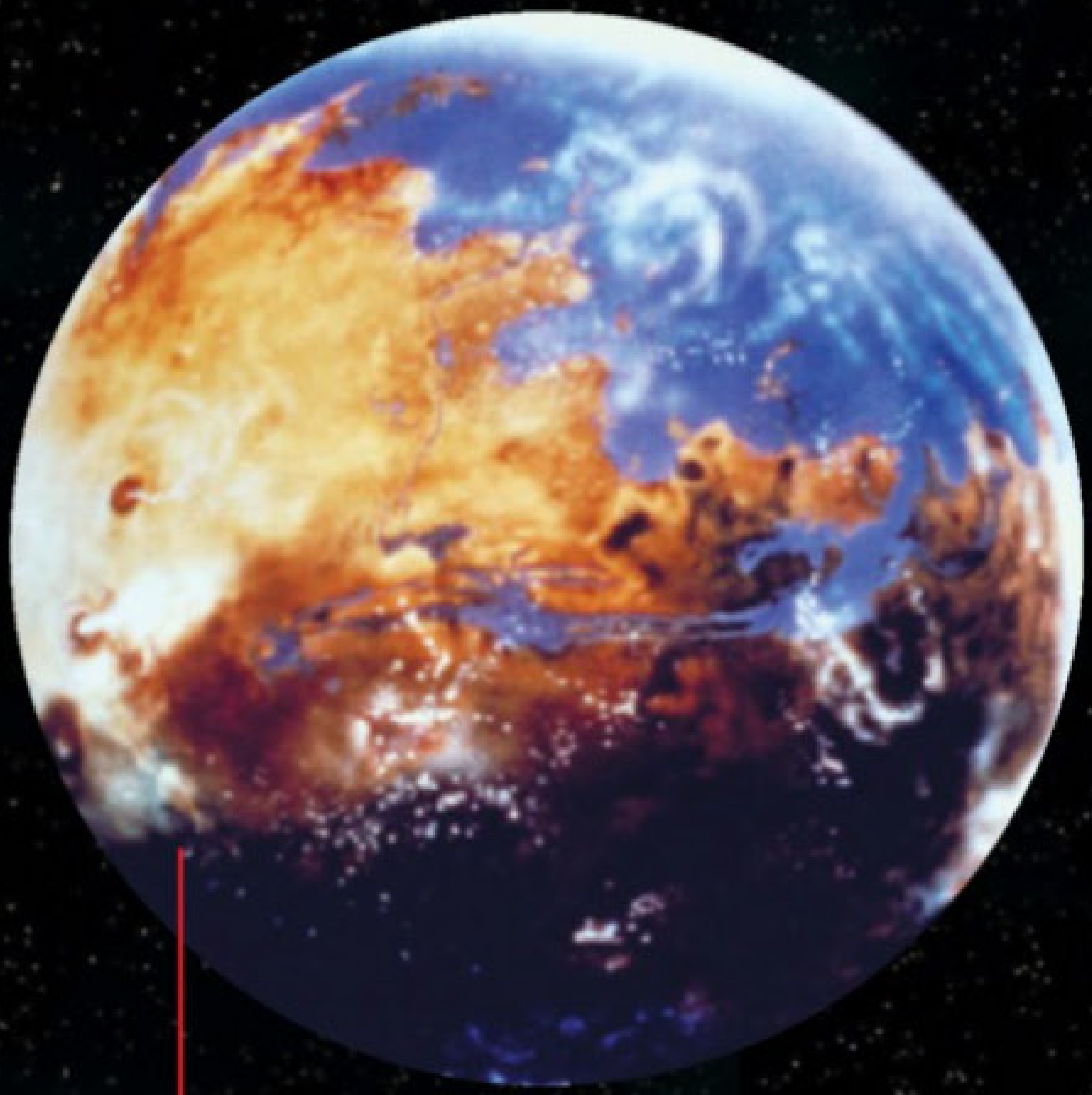
There's evidence of hydrothermal vent activity on Mars and the Spirit rover has even found deposits of pure silica. On Earth, such deposits are only formed by hot water reacting with rock, for example at a hydrothermal vent. Silica deposits often contain the fossilised remains of life, but Spirit wasn't equipped to search for biological signatures, so it's still unknown whether life was present in these vents.

Despite promising early conditions, the surface of Mars did not remain hospitable for long. As the planet cooled and lost its atmosphere 3.7 billion years ago, pressure on the surface dropped and liquid water became unstable, boiling off into the vacuum of space. This left the surface dry, frozen and dusty. Had life been beginning to emerge on Mars, this might have been a catastrophic event.

However, not all of the water was lost. The 2001 Mars Odyssey used spectrometers to search for chemical signatures of water and identified concentrated deposits of hydrogen near the poles,

Martian rocks like the Nakhla meteorite (pictured) that have fallen to Earth have enabled us to study whether Mars could have once been habitable

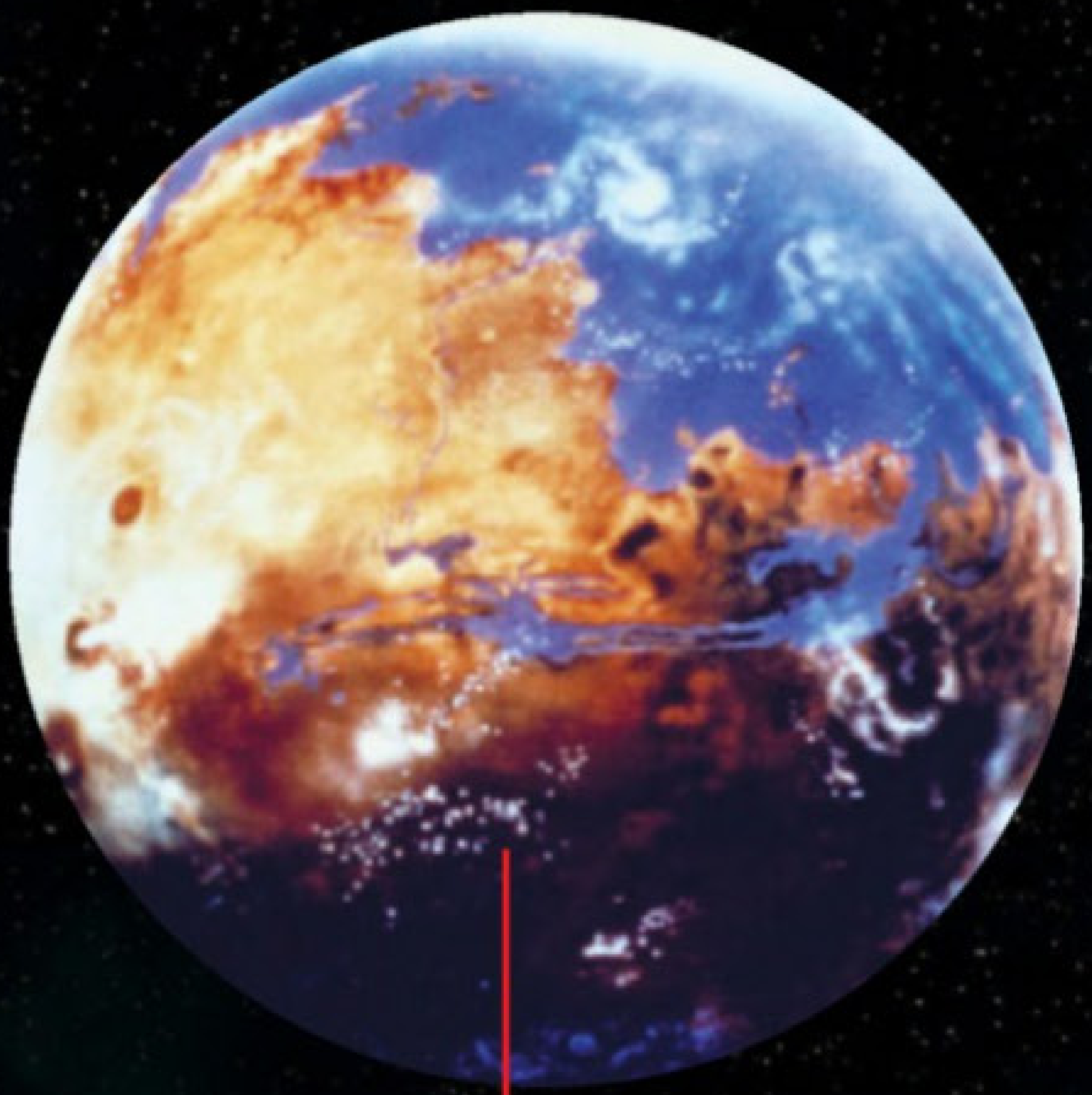
History of water on Mars



Liquid oceans

4 billion years ago

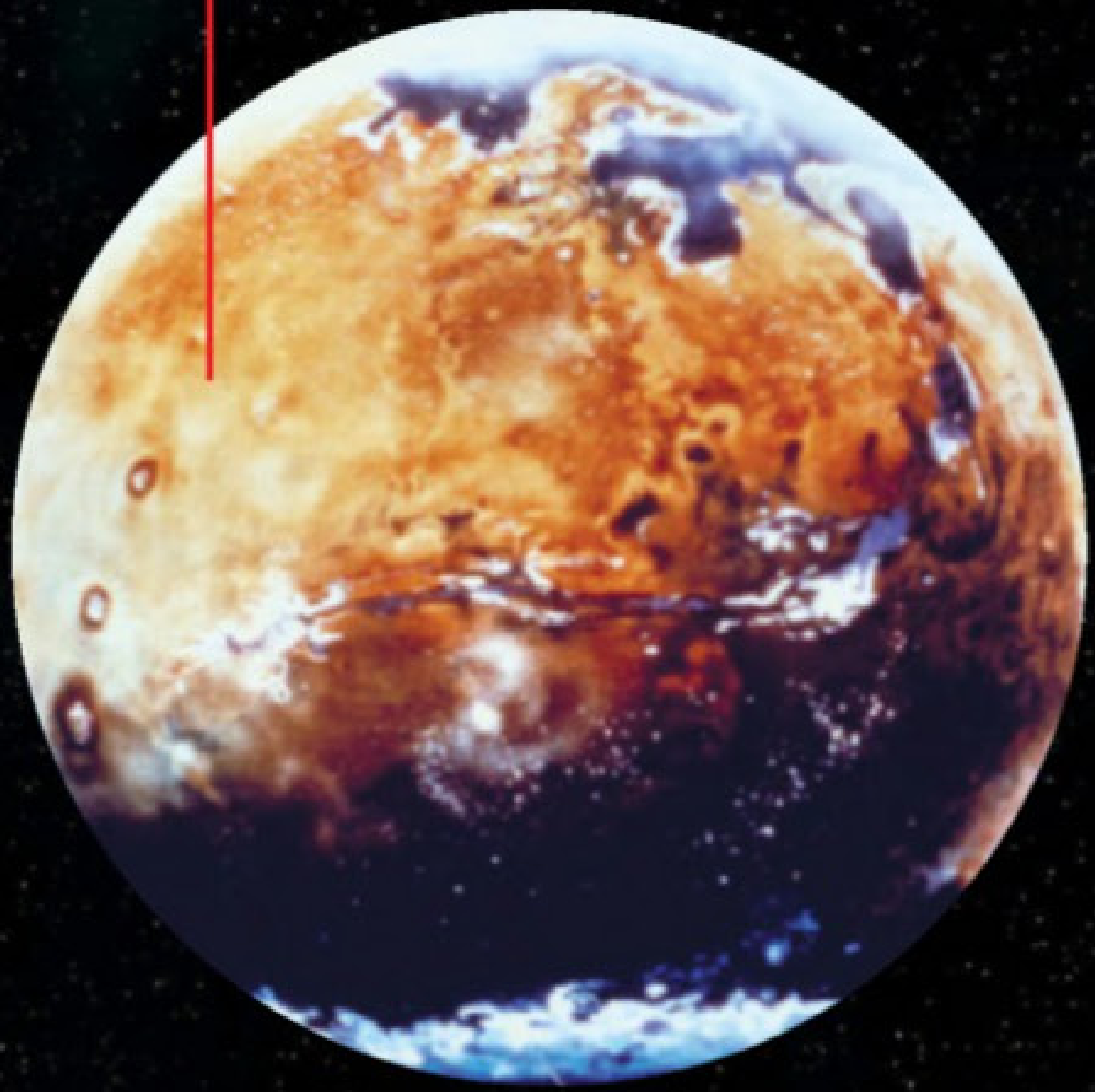
During this volcanic period, the atmosphere was thicker, the planet warmer and the late heavy bombardment delivered water-laden asteroids to the surface of the Red Planet.



Conditions for life

3.8 billion years ago

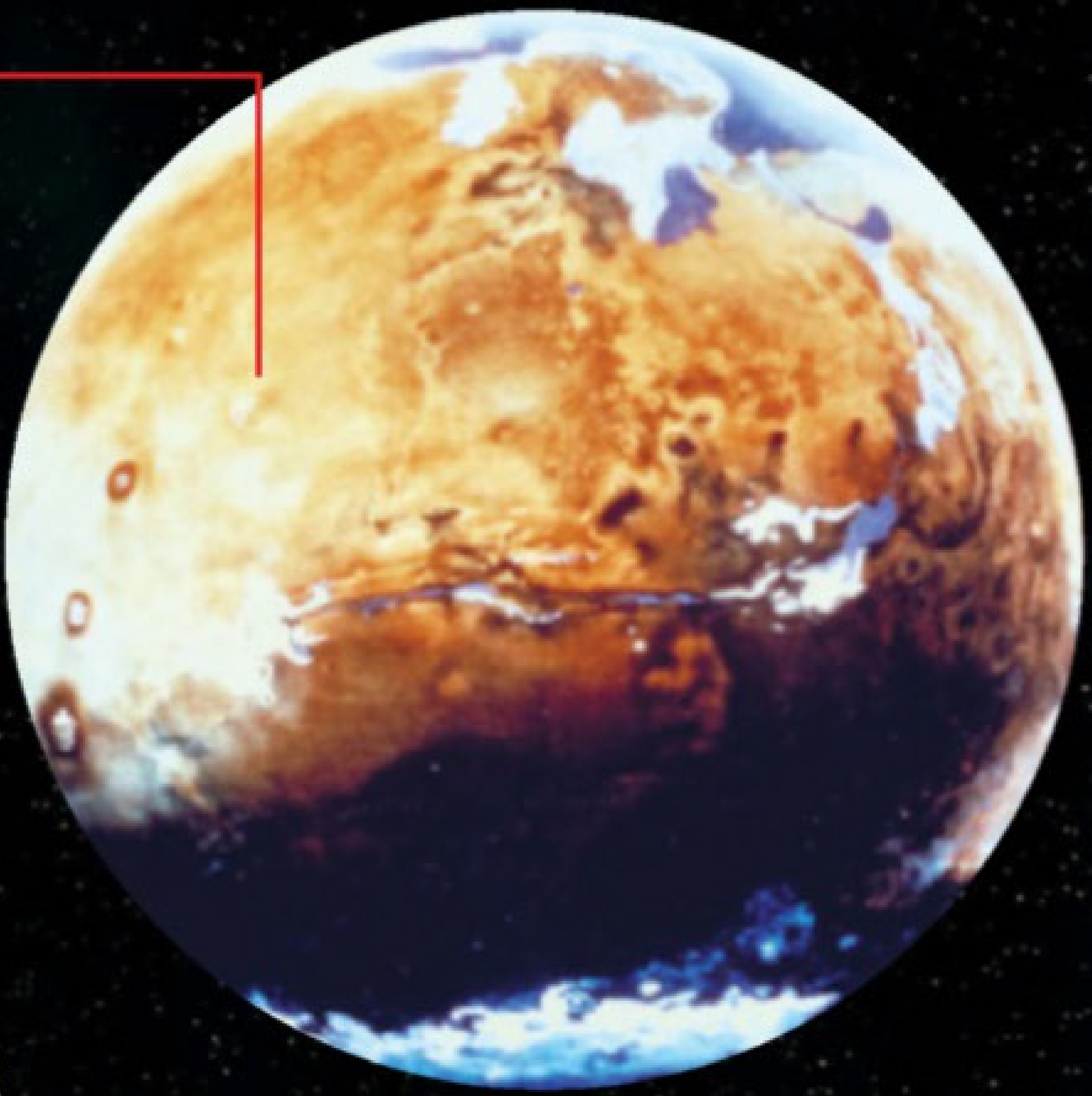
The late heavy bombardment ended and a liquid water ocean may have covered the northern hemisphere of Mars, supplying rain to the mountains in the south.



Catastrophic climate change

3.5 billion years ago

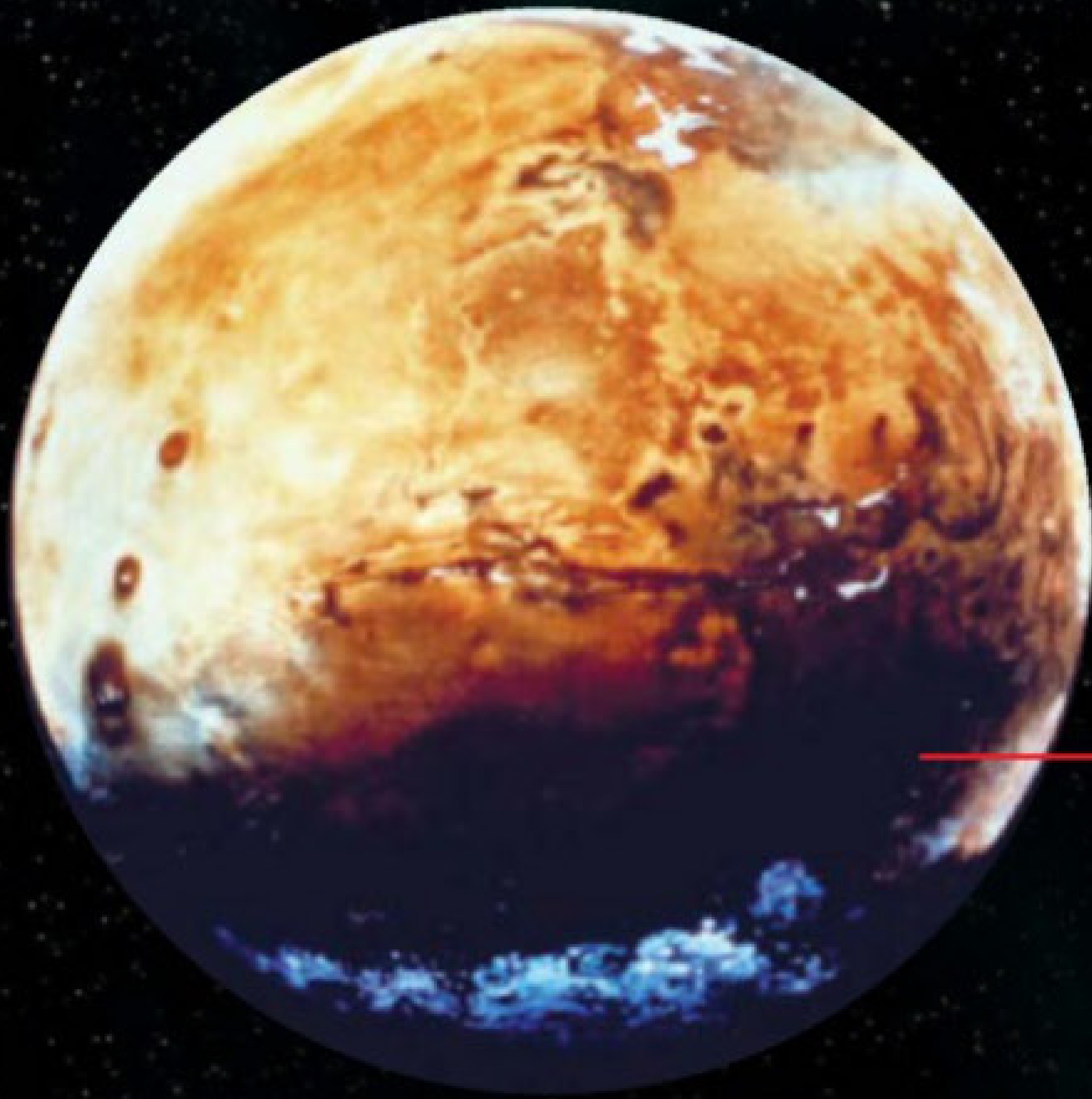
When Mars cooled, its magnetic field dissipated. Nearly all its atmosphere was lost to space and air pressure dropped so low that liquid water became unstable on the surface.



Periodic flooding

2.0 billion years ago

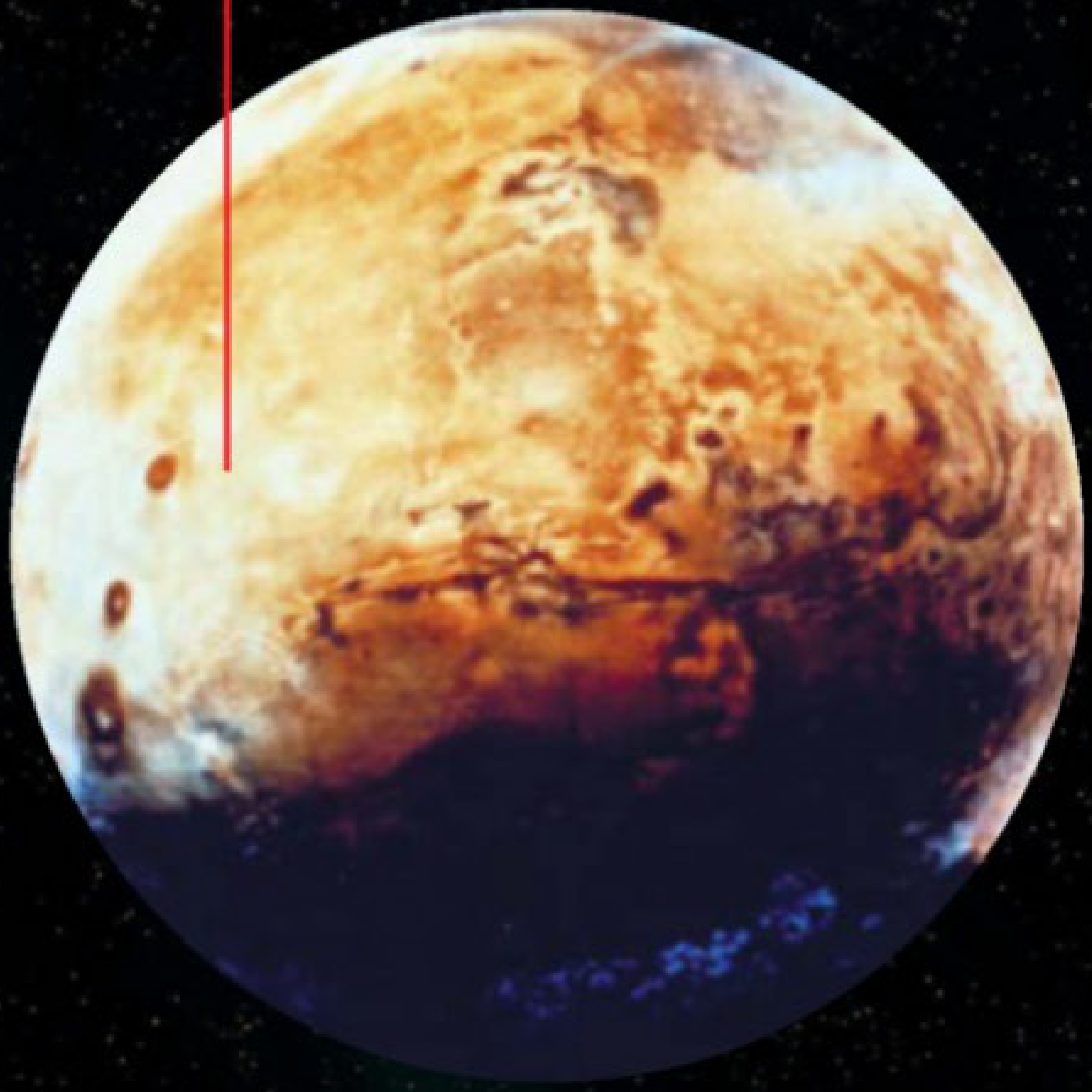
During warm periods in the history of Mars, subsurface ice melted and flooded the planet, leaving chaotic channels into the northern lowlands.



Subsurface rivers

1.0 billion years ago

Despite harsh surface conditions, evidence of fresh gullies is apparent on crater slopes, possibly caused by melted subsurface ice dragging material on the surface before refreezing.

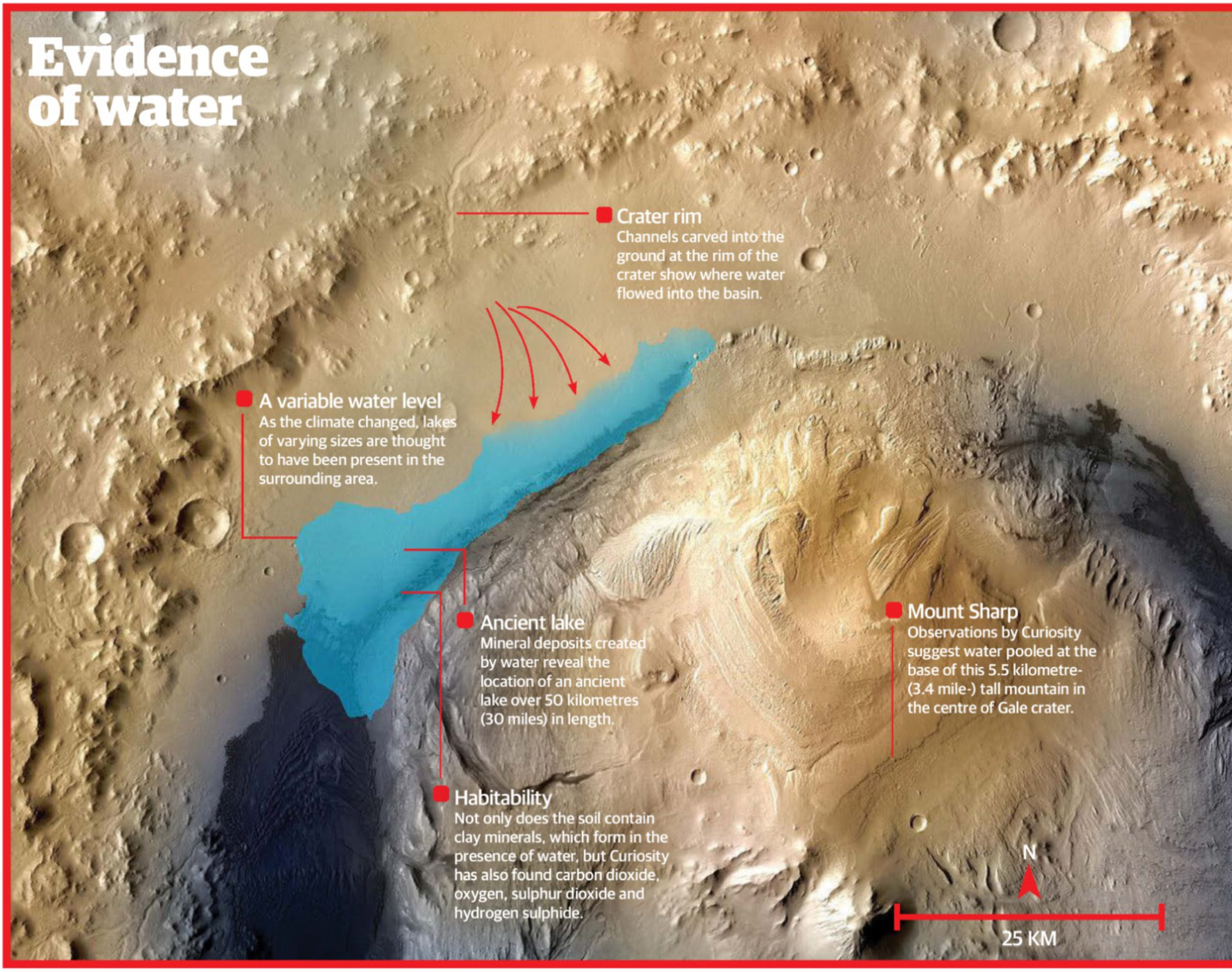


Ice and aquifers

Present day

The surface of Mars is covered in permafrost and there may still be liquid water beneath the surface, heated by the residual warmth of the planet.

Evidence of water



Crater rim
Channels carved into the ground at the rim of the crater show where water flowed into the basin.

A variable water level
As the climate changed, lakes of varying sizes are thought to have been present in the surrounding area.

Ancient lake
Mineral deposits created by water reveal the location of an ancient lake over 50 kilometres (30 miles) in length.

Mount Sharp
Observations by Curiosity suggest water pooled at the base of this 5.5 kilometre- (3.4 mile-) tall mountain in the centre of Gale crater.

Habitability
Not only does the soil contain clay minerals, which form in the presence of water, but Curiosity has also found carbon dioxide, oxygen, sulphur dioxide and hydrogen sulphide.

a sign of water ice. Since then it's been confirmed that Martian soil contains between 2 and 60 per cent water by weight and a large proportion of the surface soil is covered in permafrost. On Earth, permanently frozen soil is a rich source of well-preserved biological material and several species of single-celled organisms are capable of surviving for extended periods of time frozen in suspended animation. It's therefore conceivable that had life evolved when Mars was warm and wet, there might be evidence of it trapped within the ice. Even more interestingly, in some areas on Earth, cold-loving extremophiles known as psychrophiles actually live in the permafrost, surviving in thin veins of water kept liquid by a high salt content.

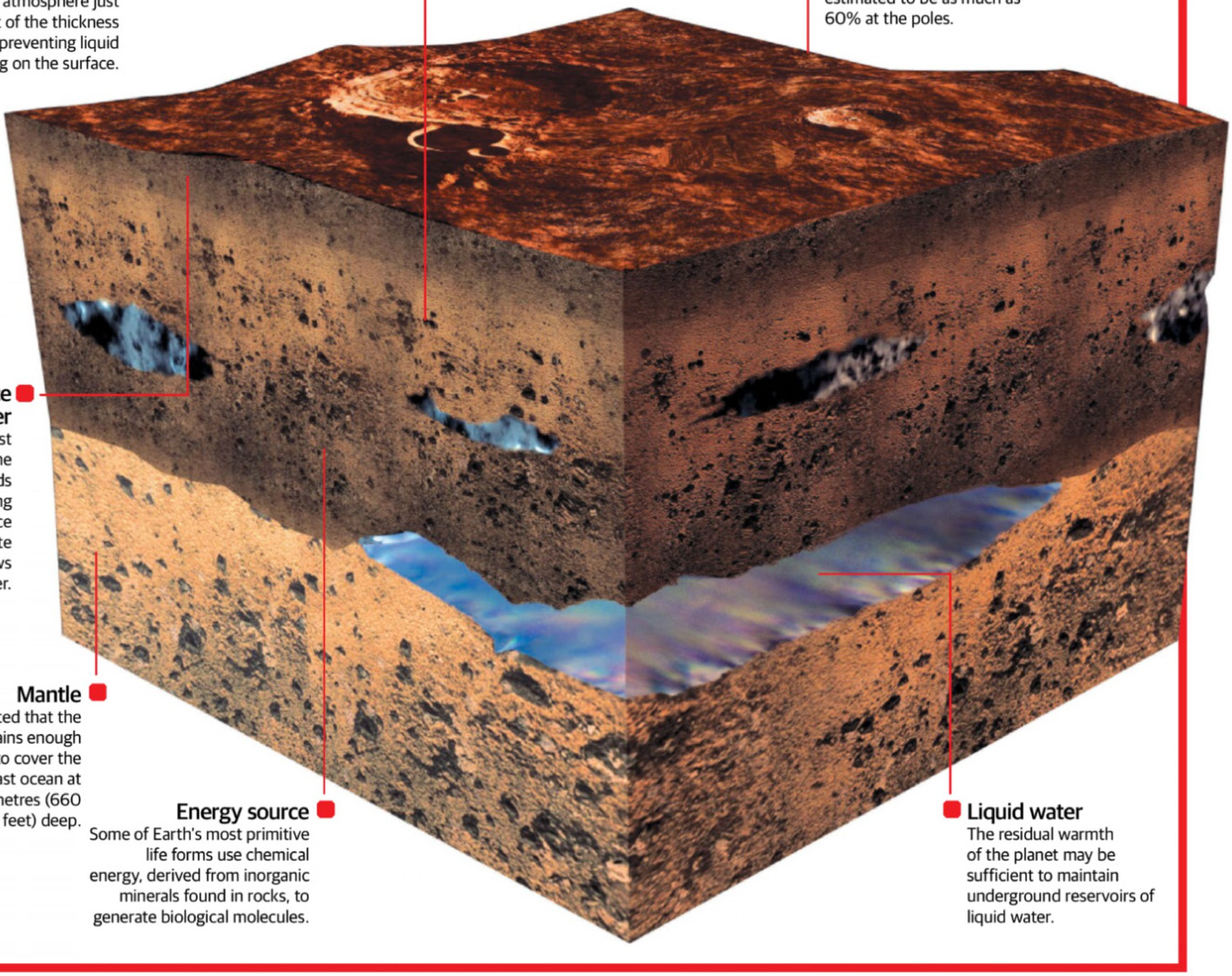
Periods of volcanic activity are thought to have periodically melted areas of ice on Mars, enabling streams to flow across the surface, churning the minerals and leaving detectable clay deposits, before freezing or evaporating. Analysis of surface sandstone has indicated that this water was incredibly salty, but not necessarily uninhabitable. Halobacteria on Earth can survive environments saturated with salt, using light from the Sun in a primitive form of photosynthesis in order to generate energy.

Perhaps the most exciting possibility is that liquid water might still be present below the surface of Mars. The volcanoes on the surface are relatively free of impact craters, suggesting that the planet was, at least until recently, geologically active. It's possible that residual heat under the crust could maintain pockets of liquid water. This hypothesis is supported by images from the Mars Global Surveyor, which entered orbit in 1997 and scanned the entire surface of the planet. It uncovered features resembling Earth aquifers, underground layers of permeable rock filled with water. The surface of the planet might be bathed in damaging ultraviolet radiation, but shielded beneath the ground there is a chance that primitive life forms might be able to survive.

The likelihood of finding complex multi-cellular life on Mars, ancient or modern, seems low. Sustaining more than one cell requires huge amounts of energy and on Earth the evolution of complex life was very much dependent on the Sun and the atmosphere. 2.7 billion years ago, the oxygen level in Earth's atmosphere began to rise, driven by the evolution of photosynthesis. Photosynthetic

> "Had life evolved when Mars was warm and wet, there might be evidence of it trapped within the ice"

Under the surface



Thin atmosphere
Mars has an atmosphere just one per cent of the thickness of Earth's, preventing liquid water existing on the surface.

Permafrost
On Earth many microbial species can survive frozen in permafrost and some actually live within the ice, hidden in veins of salty water.

Surface soil
Samples of Martian surface soil analysed by Curiosity are around two per cent water by weight, but these levels are estimated to be as much as 60% at the poles.

Subsurface water
Lying just beneath the surface, periods of local warming melt the ice to generate transient flows of saltier water.

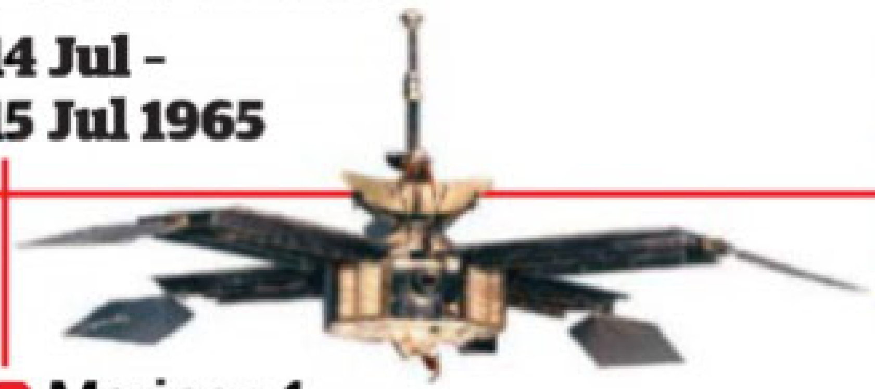
Mantle
It's estimated that the mantle contains enough water to cover the planet in a vast ocean at least 200 metres (660 feet) deep.

Energy source
Some of Earth's most primitive life forms use chemical energy, derived from inorganic minerals found in rocks, to generate biological molecules.

Liquid water
The residual warmth of the planet may be sufficient to maintain underground reservoirs of liquid water.

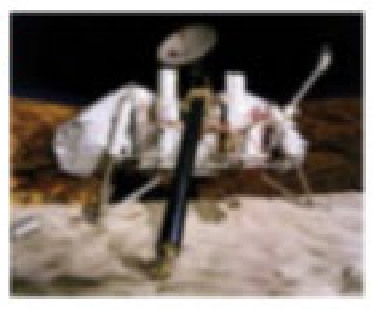
The search for life

14 Jul – 15 Jul 1965



Mariner 4
This spacecraft captured the first images of Mars, effectively halting the search for intelligent life on the planet, but paving the way for research into its biological history.

20 Jul 1976 – 13 Nov 1982



Viking probes
This pair of probes showed the surface of Mars to be covered in valleys, rifts and stream networks.

Jan 24th 2004 – still active

Mars Exploration rovers
The Spirit and Opportunity rovers (the latter still active) analysed rock and soil samples, demonstrating that the surface of Mars contains minerals that usually form in the presence of liquid water.

25 May 2008 – 2 Nov 2008

Phoenix lander
Just one month after the Phoenix lander touched down on the surface of Mars, NASA confirmed that it had found water ice.

NASA's Viking landers were the first to search for signs of life on the surface of Mars

organisms are able to use energy from light to convert carbon dioxide and water into biological molecules, releasing oxygen as a by-product.

Oxygen is highly reactive and can be used to burn carbohydrates, generating the huge amounts of energy required to maintain larger, energy-hungry life forms. However, Mars is much farther from the Sun and by the time photosynthetic organisms were beginning to emerge on Earth, the surface of the Red Planet was so inhospitable that access to daylight would have been greatly challenging for any fragile attempts at life.

Based on the chemistry of the rocks on the surface of the planet, the local environment and knowledge of life on Earth, it's possible to imagine the kinds of life forms that might be able to survive in the various biologically hospitable niches on Mars. However, as yet there is no real evidence that life has ever existed on the planet. So far all we know for sure is that there is water on Mars and that in the past this likely pooled in surface lakes and streams; Mars was habitable, but that does not necessarily mean there was any form of life.

The next challenge is to find biological materials, particularly organic carbon - the scaffold element that makes up the backbone of biological molecules. On Earth, fossil records provide information about our past, and identifying which rocks might have preserved biological material on Mars is a major new goal for experts.

NASA currently has two rovers on the Red Planet, Curiosity and Opportunity, as well as the two orbiters Odyssey and the Mars Reconnaissance Orbiter. This arsenal of technology will soon be expanded, as the recently launched MAVEN orbiter arrives to analyse the upper atmosphere and the InSight lander, launching in 2016, begins to study the interior of the planet. The two most exciting upcoming missions to keep an eye on will be NASA's 2020 Mars Rover and the European Space Agency's 2016 and 2018 ExoMars missions. Both will carry astrobiology instruments designed to hunt for the evidence of life. ■

What would Martian life be like?

Charles Cockell, professor of astrobiology at the University of Edinburgh, on the possibilities of life on Mars

Given what we know about the conditions on Mars, past and present, what sort of life forms might you expect to see?

"I think if there were anything there, it would be very simple and it would probably use quite basic sources of energy. One example could be microbes that use hydrogen and carbon dioxide to make methane. Methane hasn't actually been detected on Mars, but that is one of the most primitive types of energy-gathering. Those are the sorts of things you would be looking for if you were going to hunt for life."

How about complex life? Could anything larger have lived in the water?

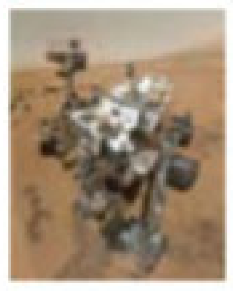
"It seems unlikely; Mars became very dry about 3.9 billion years ago. There has been episodic water since then, but the main phase of large bodies of water, lakes and rivers, seems to have been over about 3.8 to 3.9 billion years ago. [Complex] multi-cellular life only appears in the rock record on the Earth about 600 million years ago. I think that what you would probably be looking for are micro organisms, not complex life."

What are the chances of microbial life forms still existing on Mars?

"It would all depend on whether there is liquid water under the surface. The problem with Mars is that it's very much a frozen world now. People have seen what might be brine seeps, seeping water onto the surface of the Red Planet, even today. Whether these places are inhabited is difficult to know, they could be habitable but actually have no life in them. In other words, be uninhabited habitats."

Aug 6th 2012 – still active

Curiosity

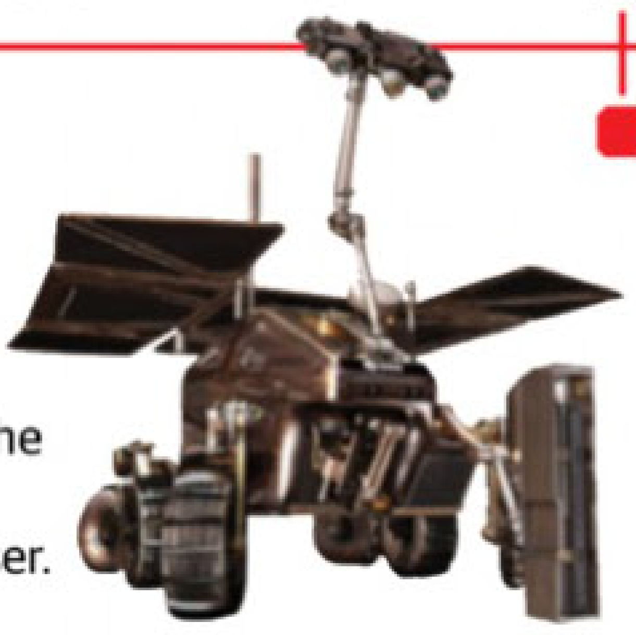


Data gathered by Curiosity has shown the Gale crater once held a lake, which could have hosted life.

Orbiter launch 2016, Rover launch 2018

ExoMars

This will search for signs of life using a long sub-surface drill, as well as the Mars Organic Molecule Analyser.



Launch 2020

2020 Mars rover

Based on the Curiosity rover, the 2020 Mars Rover will be equipped to hunt for the biological signatures of life and maybe even return a sample.

Beyond 2020

Mars sample-return mission

The proposed sample-return project is the ultimate search for life and would bring material back to Earth for analysis by our most advanced equipment.

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5 AMAZING FACTS ABOUT

Lava worlds

Lava worlds are among the least hospitable places in the universe

© SPL

Over half as hot as the Sun's surface

These rocky planets are entirely covered in molten lava and can have a surface temperature up to several thousand degrees Celsius, hot enough to melt most metals.

Can be torn apart by their stars

Similar to the way the moon Io in our Solar System is stretched and squashed by Jupiter, some lava worlds get their molten surfaces from tidal heating caused by their tight but eccentric orbits.

Earth was once in a similar state

It is thought that between two and three billion years ago Earth's surface was covered in molten lava to a depth of 10 to 15 kilometres (six to nine miles) due to an impact with a Mars-sized object.

On some lava worlds it rains rock

The exoplanet COROT-7b orbits so close to its star - 23 times closer than Mercury does our Sun - that its atmosphere consists mostly of vaporised rock, which periodically rains down on the planet.

A year on a lava world can last a few hours

Some lava worlds are planets that orbit very close to their host star. For example, Kepler 78b completes an orbit of its star, Kepler 78, in just 8.5 hours because of its close proximity to the star.

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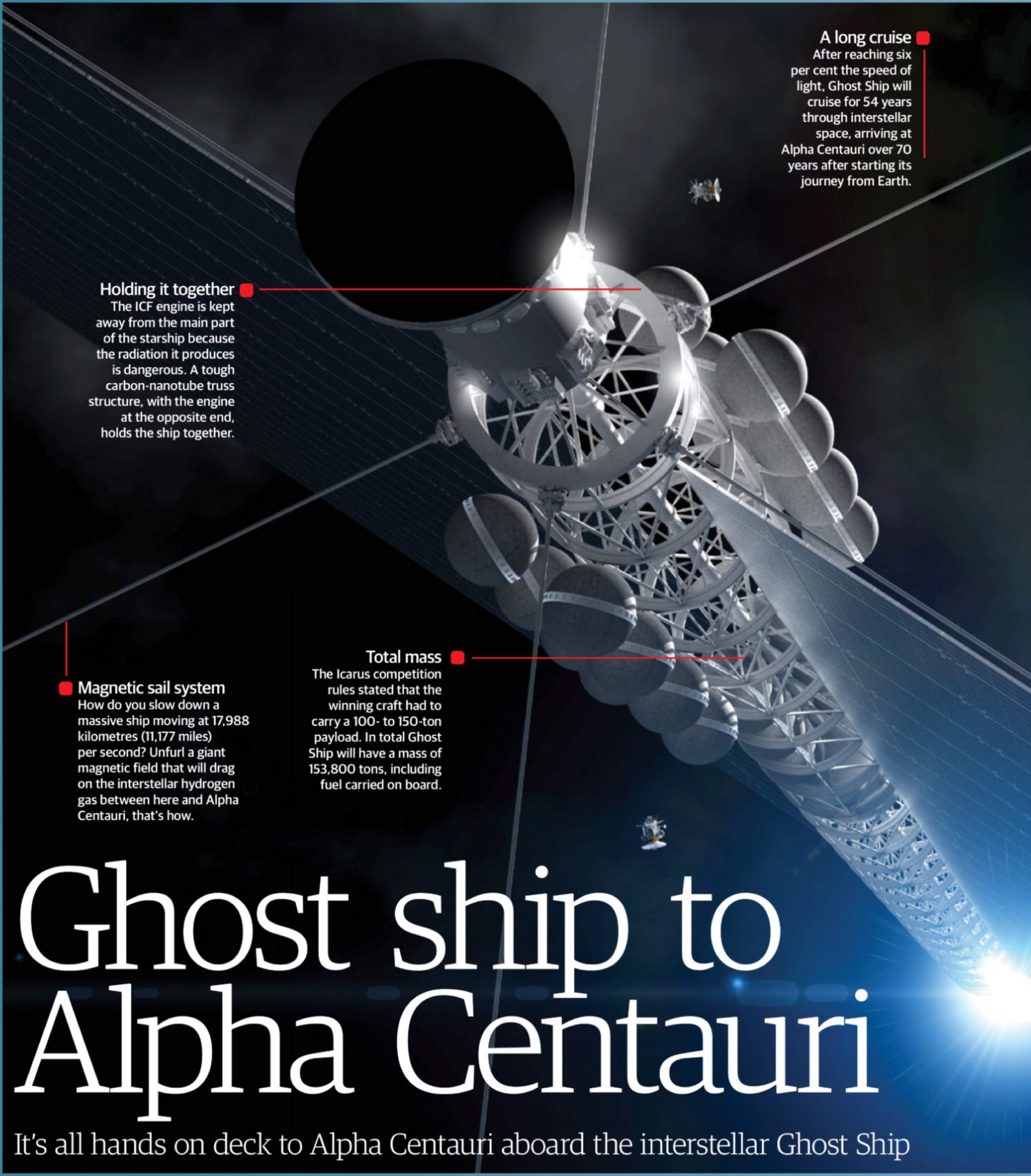
Ghost ship to Alpha Centauri

It's all hands on deck to Alpha Centauri aboard the interstellar Ghost Ship

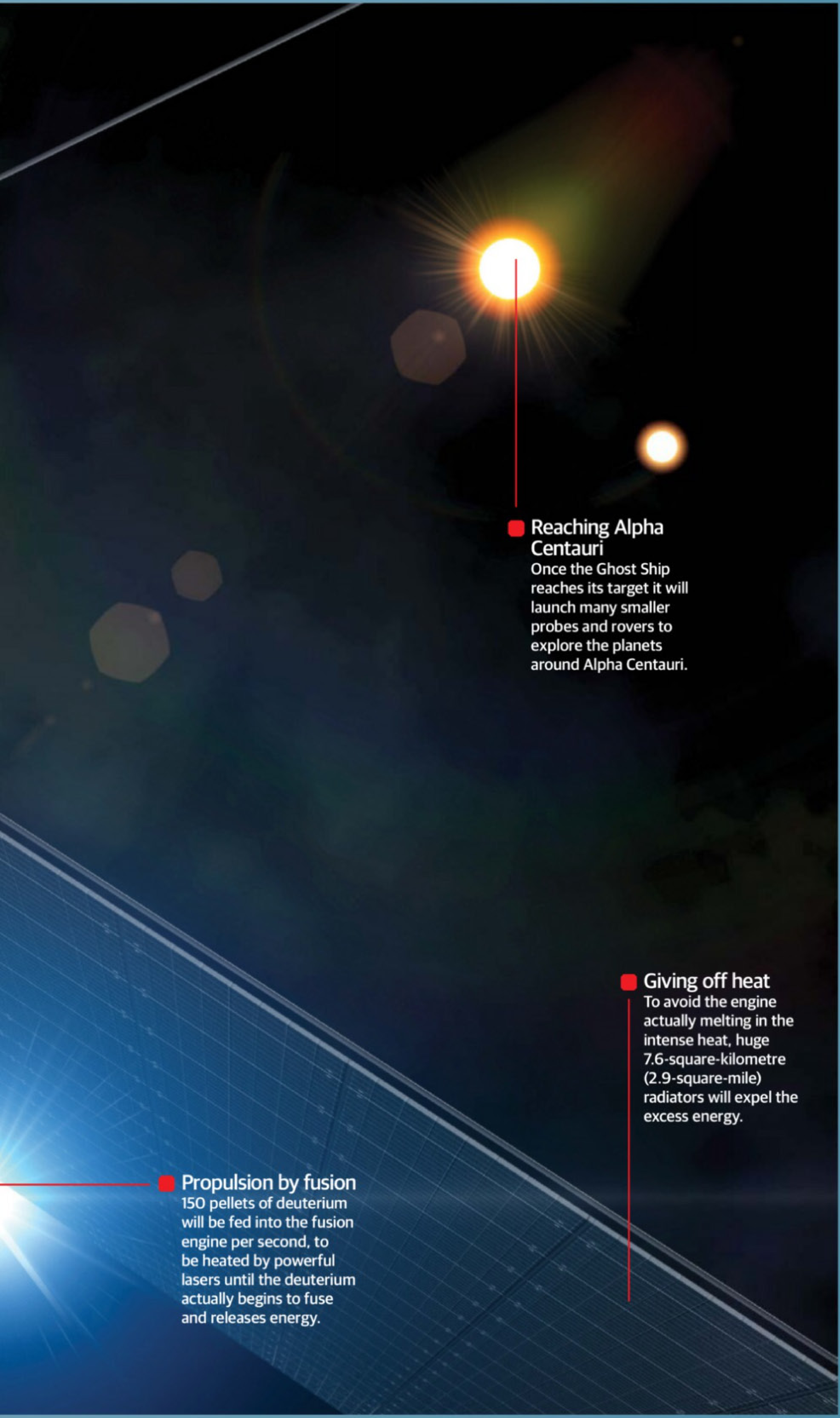


A long cruise
After reaching six per cent the speed of light, Ghost Ship will cruise for 54 years through interstellar space, arriving at Alpha Centauri over 70 years after starting its journey from Earth.

Holding it together
The ICF engine is kept away from the main part of the starship because the radiation it produces is dangerous. A tough carbon-nanotube truss structure, with the engine at the opposite end, holds the ship together.

Magnetic sail system
How do you slow down a massive ship moving at 17,988 kilometres (11,177 miles) per second? Unfurl a giant magnetic field that will drag on the interstellar hydrogen gas between here and Alpha Centauri, that's how.

Total mass
The Icarus competition rules stated that the winning craft had to carry a 100- to 150-ton payload. In total Ghost Ship will have a mass of 153,800 tons, including fuel carried on board.



Reaching Alpha Centauri
Once the Ghost Ship reaches its target it will launch many smaller probes and rovers to explore the planets around Alpha Centauri.

Giving off heat
To avoid the engine actually melting in the intense heat, huge 7.6-square-kilometre (2.9-square-mile) radiators will expel the excess energy.

Propulsion by fusion
150 pellets of deuterium will be fed into the fusion engine per second, to be heated by powerful lasers until the deuterium actually begins to fuse and releases energy.

© Adrian Mann

The destination is Alpha Centauri, a triple system of stars located some 4.37 light years away from the Sun. The system could have at least one Earth-sized world called Alpha Centauri Bb and perhaps more. To learn about and explore other stars and exoplanets closer, Alpha Centauri is our best bet but, even though it might be relatively close, getting there will be a feat in itself.

That's what Project Icarus is all about. A joint project between the British Interplanetary Society and Icarus Interstellar, its goal is to design a craft using current or near-future technology. As part of its development, Project Icarus members were encouraged to form teams to design possible propulsion schemes using nuclear fusion that could feature in the final Icarus design. The winning design was the Ghost Ship, led by Andreas Hein of the Technical University of Munich. While Ghost Ship is still only a concept, its new ignition system could be the way forward when it comes to interstellar travel.

Nuclear fusion is a popular means of generating energy when scientists consider how to reach the stars. Fusion involves two atoms, such as deuterium, tritium or helium-3, fusing into one. This releases energy in the process and is far more-efficient than nuclear fission, which splits atoms and is what runs our nuclear power stations today. In the 1970s Icarus' ancestor, a British Interplanetary Society project called Daedalus, showed that a fusion-powered starship could reach about ten per cent of the speed of light, meaning it would take 43.7 years to reach Alpha Centauri.

Ghost Ship would be a little slower, accelerating for 15.5 years up to six per cent of the speed of light, after which the 153,800-ton craft will cruise through interstellar space for 54 years. It does this using a method known as inertial confinement fusion fast ignition. Here 150 tiny pellets of deuterium are heated by powerful lasers every second, until they grow so hot and dense that the atoms inside the pellets begin to fuse, expelling large amounts of energy and lots of high-energy neutrons. This neutron radiation can be extremely dangerous, so the engine is separated from the rest of the craft on a long boom. However, the neutrons can also be gathered and recycled to provide the additional energy to power the lasers that ignite the fusion and create more of these neutral subatomic particles.

Once the ship gets close to Alpha Centauri, it will deploy a magnetic sail to drag on the hydrogen gas that lurks in deep space, slowing Ghost Ship down to one per cent of the speed of light before firing its fusion engine in reverse to complete the deceleration. Probes carrying rovers, ready to uncover the secrets of our nearest star system, will then be launched to explore. ■

> "While Ghost Ship is only a concept, its new ignition system could be the way forward"

The search for wormholes

All About Space joins the teams of scientists searching for wormholes in an attempt to uncover the facts behind the science fiction

Written by Gemma Lavender

Wormholes are so-called gateways that provide a shortcut through the fabric of space-time. They can be thought of as tunnels with ends capped by an ever-hungry black and a white hole, the black hole's time-reversed cousin that prefers to spit things out if anything comes too close to its event horizon.

It's true that a wormhole never looks out of place in science fiction, for example lurking in the universe of *Deep Space 9* and employed by captain Benjamin Sisko and his crew of the Defiant. They use the hole to travel from the Alpha to the Gamma quadrant on the other side of the galaxy at unprecedented speed - certainly a thrilling prospect.

However, we still don't know for sure whether traversable wormholes like the ones in *Star Trek* really exist. Even finding the slightest hint of these natural portals almost seems like a pipe dream. With this in mind, it would seem odd that massive organisations are still looking, such as Project RadioAstron, the Soviet Union's first radio astronomy research facility.

"The search for wormholes seems like a worthy undertaking," muses assistant professor of astrophysics Robert Owen of Oberlin College. His thoughts are echoed by Igor Novikov, a Russian theoretical astrophysicist and cosmologist who made

Interview

Why are we looking for wormholes?

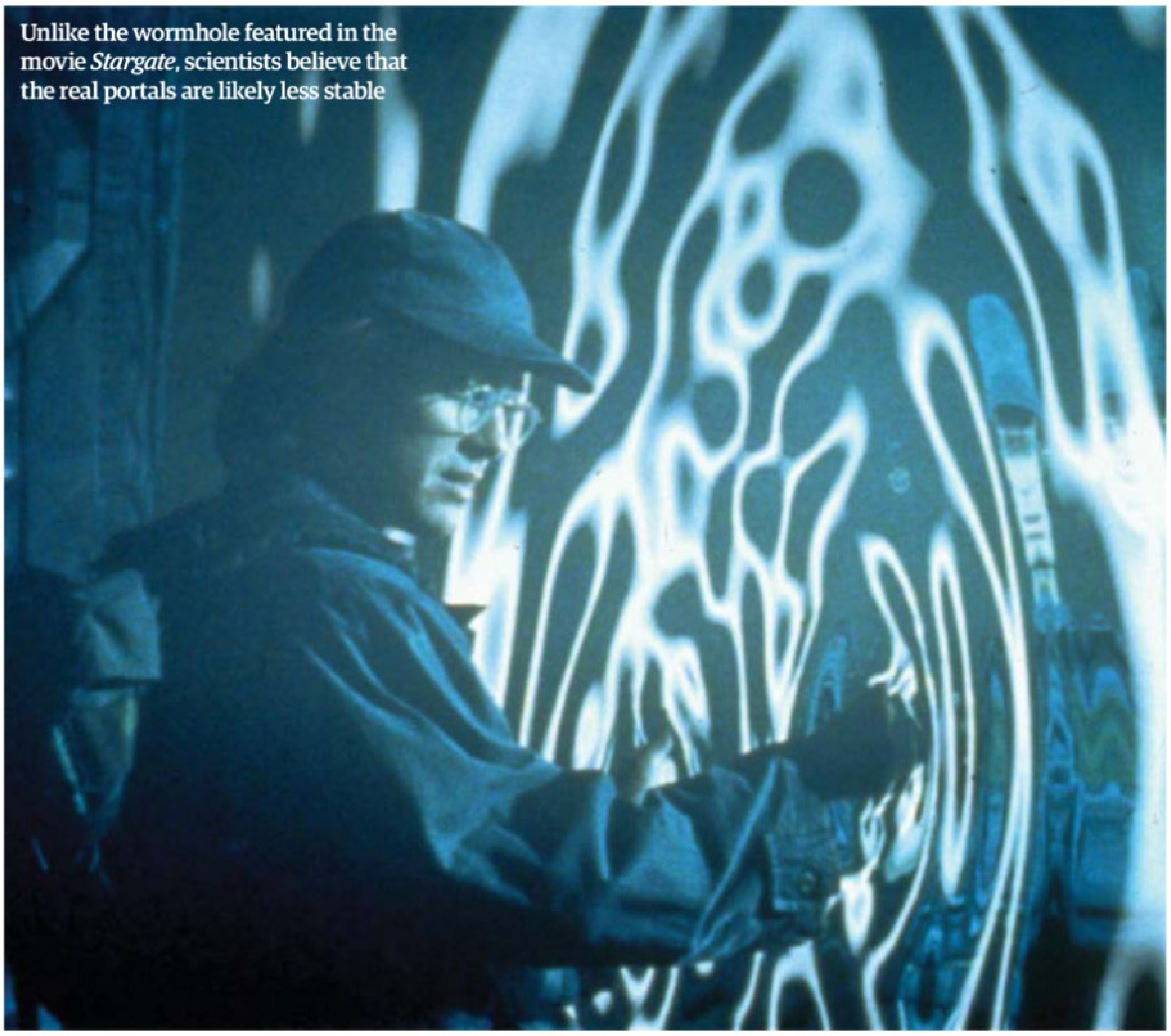
Professor Robert Owen, of Oberlin College, USA, tells us why hunting for wormholes is so necessary

"I think it's extremely important that we continue to search for and research the ideas behind wormholes. There are all sorts of [avenues for] research and we often find that some subjects are more practical than others. Obviously wormhole physics is not a very practical subject but wormholes and other exotic phenomena, provide a route to understanding some of the deepest questions about the nature of our universe - the arena of our very existence. For that reason alone, this is an exciting endeavour and deserving of support for its own sake.

"It's also important to note subjects that might seem highly impractical could eventually be central to our daily lives. Electromagnetic theory was at one time considered an impractical subject and now it's fundamental to everyday life. Quantum theory has long been viewed as an arcane body of research, but now it's essential for the inner workings of much modern technology.

"Another important point is that all research is fundamentally interconnected with insights made in one field of study often transferred into others. For example, there is a long-standing symbiosis between research in particle physics and solid-state physics - the field that provides much of our understanding of the properties of materials. There is a constant conversation between these two fields of study and ideas are regularly shared between them. In a broader sense, this occurs throughout the sciences. So there's really no way of knowing ahead of time what the eventual significance of any field of research might be.

"Einstein's general theory of relativity predicts quite clearly that if a wormhole existed, it would be unstable and we wouldn't be able to use it for practically travelling through time. However, with all scientific questions, we can't be completely certain that general relativity, in the form that we currently understand it, is the most accurate possible description of space-time in all situations. It could be that in certain situations general relativity becomes inaccurate, just as Newtonian physics becomes inaccurate near a black hole, for example. This means I certainly wouldn't rule out the idea absolutely, until we have some good astronomical evidence."



Unlike the wormhole featured in the movie *Stargate*, scientists believe that the real portals are likely less stable

an important contribution to the theory of time travel during the mid-1980s. The Novikov Self-consistency Principle states that it's impossible to make paradoxes of time. "There's a hypothesis that primordial wormholes exist and can connect some regions in our universe in the model of the multiverse," Novikov, who is based at the Russian Space Research Institute in Moscow, explains. "In this case, the search for astrophysical wormholes is a unique possibility to study the other universes."

These elusive tunnels through space wouldn't just be a major discovery in and of themselves, but could even open up avenues to bigger things - possibly even answering some of the deepest questions about the nature of our universe. Although we haven't found them yet, the laws and complex equations that underpin Einstein's theory of general relativity say that, technically, they should exist out there somewhere - maybe as microscopic structures the size of atoms, or giant but impassable wormholes connecting the black holes in the centres of galaxies. However, should a stable wormhole be found, it might be possible to travel down it and end up in another place, and another time, in the universe.

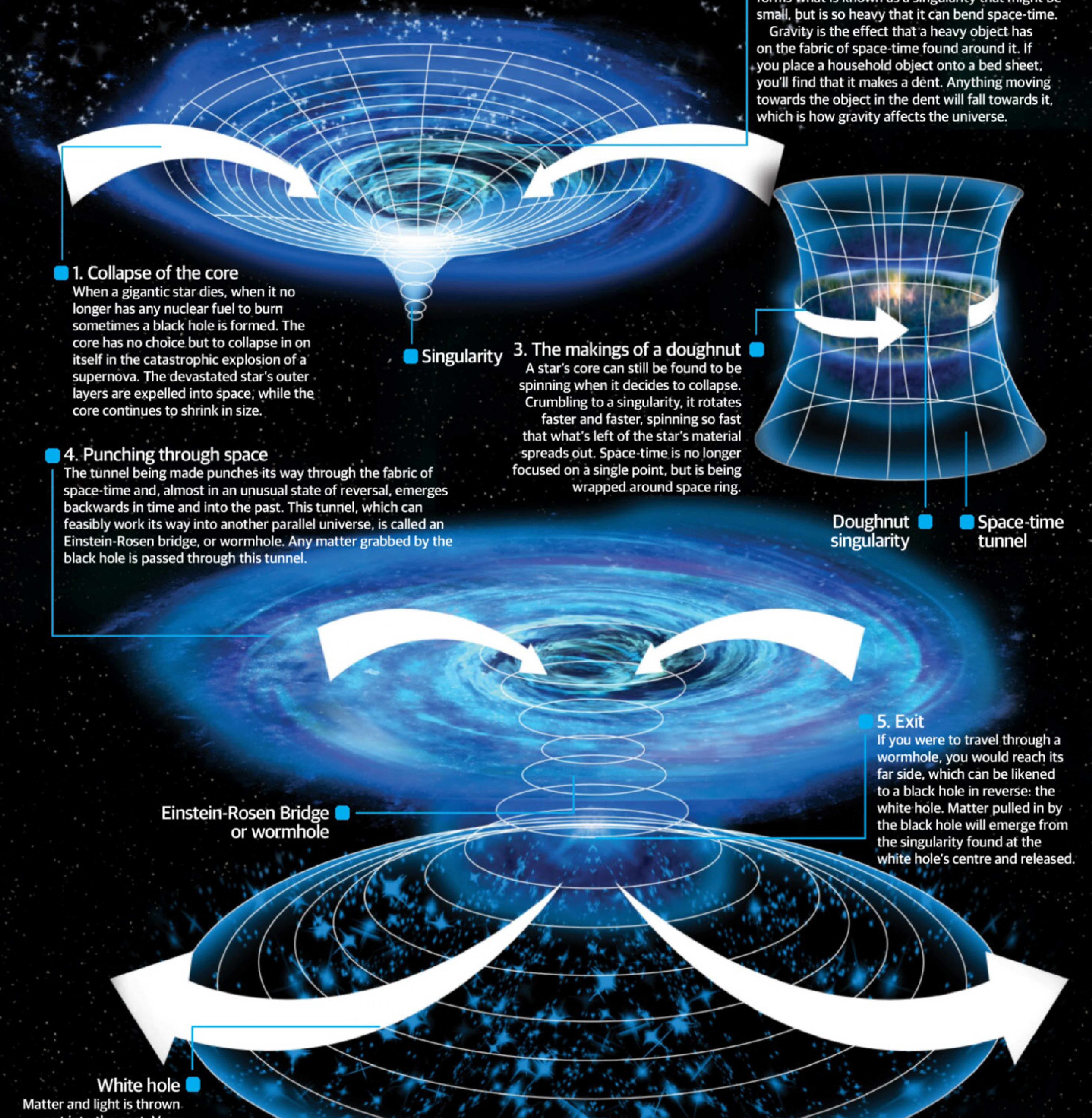
Clearly the practicalities of finding a wormhole is a challenging subject entirely on its own and one that scientists like Owen relish. The search wouldn't merely mean searching for the wormholes themselves, but the equally elusive white holes that are supposedly tacked onto one end, making the task of locating them all the more difficult. However, despite this, Owen believes that despite the obvious difficulties, the hunt for wormholes must be supported. He studies the relativistic effects of black holes and neutron stars colliding to make gravitational waves - ripples in the curvature of space-time - to find traces of the holes.

So, is finding a wormhole really that important at all? **All About Space** asked theoretical physicist Kristan Jensen at the University of Victoria. Alongside Andreas Karch, a professor of physics at the University of Washington, Jensen looks at wormholes purely from a theoretical perspective. "Honestly, no," he initially answers. "I find it unlikely that there are wormholes [of notable size] in our universe." This is because he - as well as quite a few in the scientific community - believe that we might be hard-pressed to find these tunnels through space. Paradoxically, it seems that the theory suggesting that wormholes exist also makes an equally strong case for how they could never be real.

If you were to open up a wormhole, you might find it quickly begins to fall apart. Egyptologist and linguist Daniel Jackson, the protagonist in *Stargate*,

> "In general relativity, time travel is actually one of the things that naturally comes along with wormholes" **Prof Robert Owen**

The making of a wormhole



Black hole

Everything – from matter to light – is pulled into a high-gravity black hole. Quite confusingly, this is the future end of the wormhole.

1. Collapse of the core

When a gigantic star dies, when it no longer has any nuclear fuel to burn sometimes a black hole is formed. The core has no choice but to collapse in on itself in the catastrophic explosion of a supernova. The devastated star's outer layers are expelled into space, while the core continues to shrink in size.

2. A cosmic plug hole

Shrinking smaller and smaller, the core continues to pale in significance compared with its former stellar glory. While it has shrunk to a speck, all of its mass is concentrated in a very small area. This forms what is known as a singularity that might be small, but is so heavy that it can bend space-time.

Gravity is the effect that a heavy object has on the fabric of space-time found around it. If you place a household object onto a bed sheet, you'll find that it makes a dent. Anything moving towards the object in the dent will fall towards it, which is how gravity affects the universe.

3. The makings of a doughnut

A star's core can still be found to be spinning when it decides to collapse. Crumbling to a singularity, it rotates faster and faster, spinning so fast that what's left of the star's material spreads out. Space-time is no longer focused on a single point, but is being wrapped around space ring.

4. Punching through space

The tunnel being made punches its way through the fabric of space-time and, almost in an unusual state of reversal, emerges backwards in time and into the past. This tunnel, which can feasibly work its way into another parallel universe, is called an Einstein-Rosen bridge, or wormhole. Any matter grabbed by the black hole is passed through this tunnel.

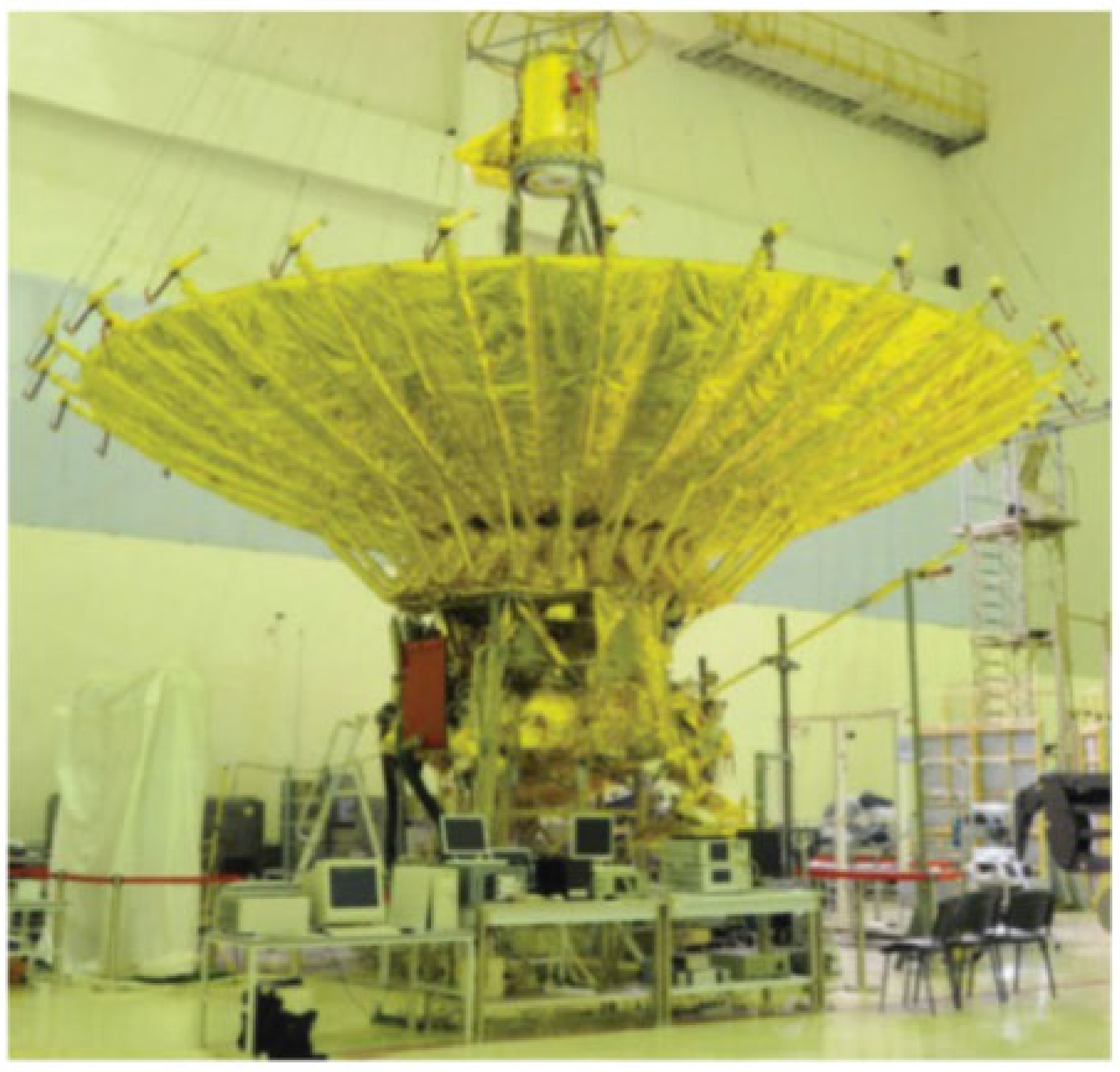
5. Exit

If you were to travel through a wormhole, you would reach its far side, which can be likened to a black hole in reverse: the white hole. Matter pulled in by the black hole will emerge from the singularity found at the white hole's centre and released.

White hole

Matter and light is thrown out into the past. Very much like a smaller version of the Big Bang.

Space radio telescope Spektr-R launched in 2011, is part of Russian venture Project RadioAstron



The telescope took its first readings on 27 September, capturing the ancient star Cassiopeia A

"All you need to enter a wormhole is a spacecraft. Just dive in and go" **Dr. Eric Davis**

might have found himself cautiously stepping into a stable wormhole when he cracked the code behind the hieroglyphics that opened a pathway to another galaxy. The reason that we might not be able to find a wormhole could simply be that in reality they're incredibly unstable entities.

Owen suggests that you just need to think about travelling through one to get a full picture of why this is. "In general relativity, time travel is actually one of the things that naturally comes along with wormholes," he says. "However, the idea that wormholes could be used for travelling through time is usually taken as an indication that they probably couldn't exist." Owen references several calculations that have been processed, showing that wormholes naturally destroy themselves before they could even offer us the chance to be used to travel back in time. "Imagine that I had a wormhole with both throats [in other words, both openings to the wormhole], in my office and I could step into one of them and emerge from the other ten seconds earlier," he describes. "For those ten seconds there would actually be two of me in the office. But what if I then chose to wait those ten seconds and then step through [the black hole again], simultaneously with my earlier self?" The answer is that Owen and his past self would again emerge from the white hole ten seconds earlier and there would now be three of him in the office. "If I did it again, there would be four of me, five, six and so on," he continues. "This silly story illuminates the way that a wormhole would naturally destroy itself."

Owen is talking about feedback, just like the feedback you might get on a microphone, because it's not just people that could take a trip though these time-tunnelling wormholes. Radiation, be it light or heat, can also enter the wormhole and do exactly the same thing as the multiple Robert Owens. So much energy would end up in the loop that it would cause the wormhole to collapse.

Another problem is that a wormhole would be too small for a single person – let alone a spaceship capable of interstellar travel – to be able to comfortably fit through. To successfully pass through a hole, we would need to find some way of enlarging one, something that seems unfeasible given that we don't even yet have proof of its existence.

However, not everyone thinks that the journey would be entirely impossible. One of the world's

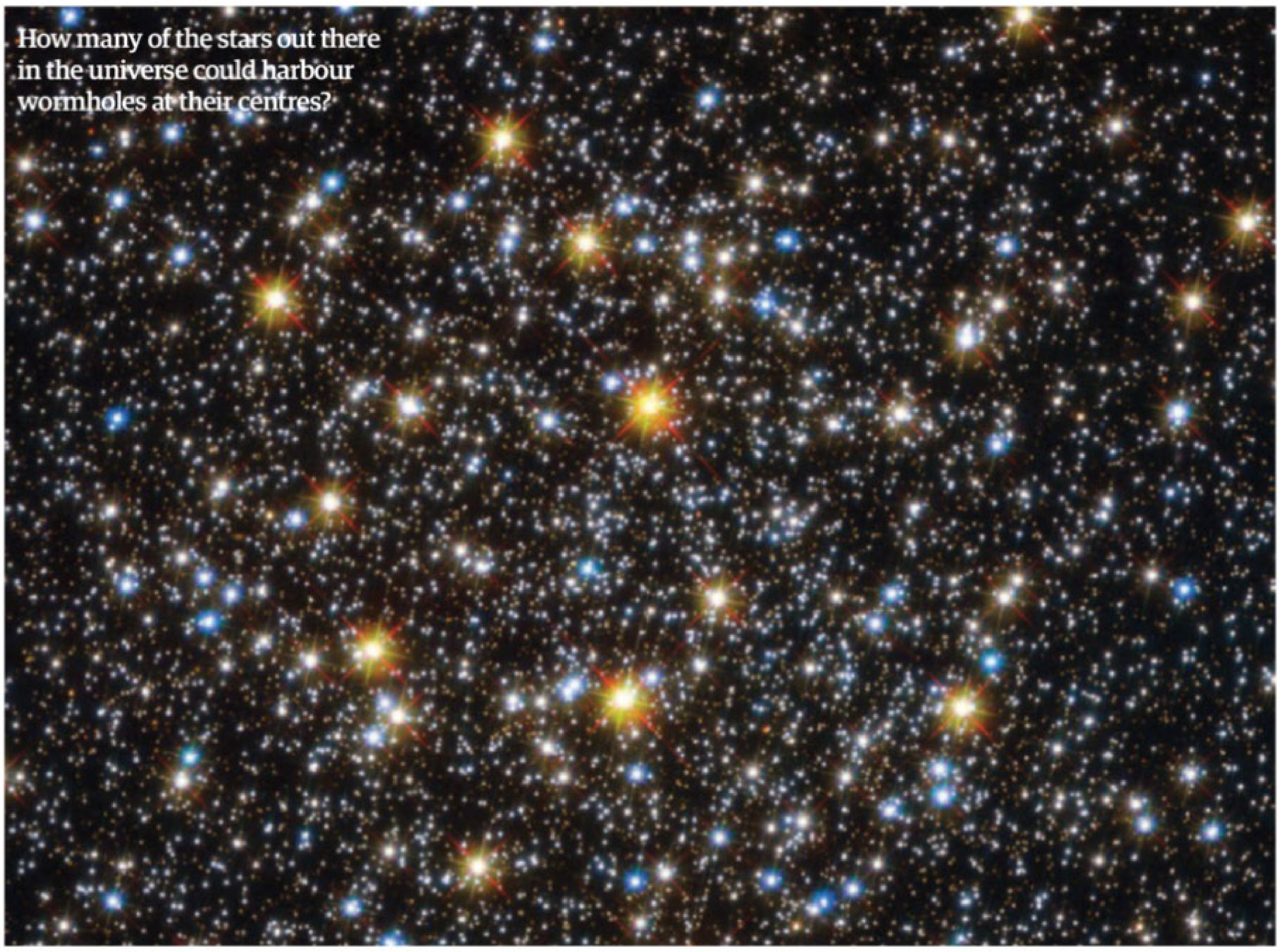
Scientists behind Project RadioAstron suspect a wormhole is at the centre of quasar 3C273, due to its increase in temperature and odd magnetic field

leading theoretical physicists, Kip Thorne, is professor emeritus at the California Institute of Technology (Caltech) and a long-time friend of both Stephen Hawking and the late Carl Sagan. Thorne not only thinks that these portals might exist somewhere out there, but that they could also be used as some kind of time machine, capable of getting us from one place in the universe to another.

Another scientist who has confidence in the possibility of using wormholes for travel is Eric Davis, a senior research physicist at the Institute for Advanced Studies at Austin, Texas. "All you need to enter a wormhole is a spacecraft. Just dive in and go," he says. "If the wormhole is too small for a spacecraft, then it has been posited by Kip Thorne, the man who discovered suggestions of traversable wormholes in Einstein's theory of general relativity, that all one may need to do is feed the wormhole more negative energy density and/or more-negative pressure to inflate it up to a larger size."

So, what is negative energy? Dark energy, which is causing the universe to expand, is an example of a negative energy pressure – something that is opposing forces such as gravity. However, we don't even know what dark energy is, let alone any way to create true negative energy, suggesting that we won't be venturing down a wormhole any time soon.

Still, this isn't to say that nature hasn't found a way to enlarge wormholes, which is exactly what Russian scientists working on Project RadioAstron are banking on. They are using the largest space telescope ever launched – not Hubble or the Herschel



How many of the stars out there in the universe could harbour wormholes at their centres?

Debate

Are wormholes likely to exist?

Two experts give their opinions on whether or not we'll ever find these tunnels piercing through space-time

Yes

Dr Eric Davis, senior research physicist at the Institute for Advanced Studies

"Yes, wormholes should exist in nature, because they are predicted by Einstein's theory of general relativity, which is the theory that also predicted black holes, cosmology, neutron stars, the gravitational lensing of galaxies, gravitational redshift and time dilation, the bending of light by stars (gravitational lensing) among other things.

"All of these astrophysical phenomena have been repeatedly observed to high precision and so verify the general relativity theory. There is no reason why wormholes shouldn't exist based on a very well-tested theory whose other predictions have been verified as previously mentioned. Another prediction of general relativity is the existence of gravitational waves [which could form an indication of the existence of wormholes], and there has been a search for their existence going on for over 50 years. This search is now ramping up with a major British astronomy program dedicated entirely to detecting them."

No

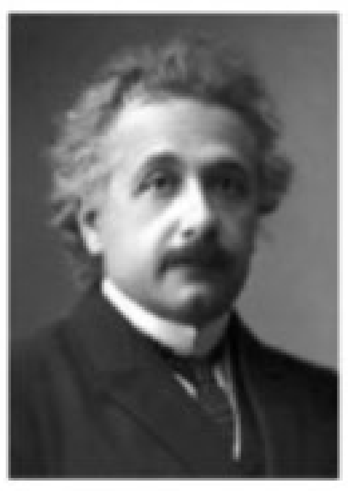
Professor Andreas Karch, a professor of physics at the University of Washington

"No, I would completely agree that most likely they are just a theoretical construct. It's very unlikely that we will ever see the more-standard kind of wormhole – the one that you could traverse through, as seen in science-fiction movies.

"According to our understanding of physics, these traversable wormholes seem almost impossible and we certainly haven't seen one. Even if they exist, I'm not sure how to hunt for them. One couldn't measure the existence of a wormhole directly without sending in two observers into the two connected black holes [which could also form the basis of a wormhole]. If they meet in the middle, there's a wormhole. If not, then there's no wormhole. In any event, the more-fortunate external observers would never know the outcome of the experiment.

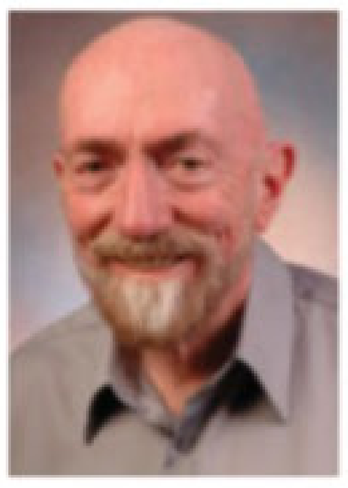
"Of course, that doesn't mean that one should stop looking – we should always look for what's out there, however, I wouldn't hold my breath."

The story of the wormhole



Building bridges

In 1935 Albert Einstein and Nathan Rosen were the first scientists to come up with the idea of wormholes. They described how their theory presents a description of space by means of two sheet, while a spatially finite bridge connects these sheets. Technically they are known as Einstein-Rosen Bridges, but the American physicist John Wheeler introduced the term wormholes for them in 1957.



Clocks run slower

Kip Thorne theorised that wormholes can act as time machines. Imagine you have a wormhole and you take one mouth of it and accelerate it close to the speed of light, before bringing it back. According to special relativity, time runs slower for things moving near the speed of light, so a clock inside the accelerated mouth would show an entirely different time from the static end of the hole.

The Mad Scientist Paradox

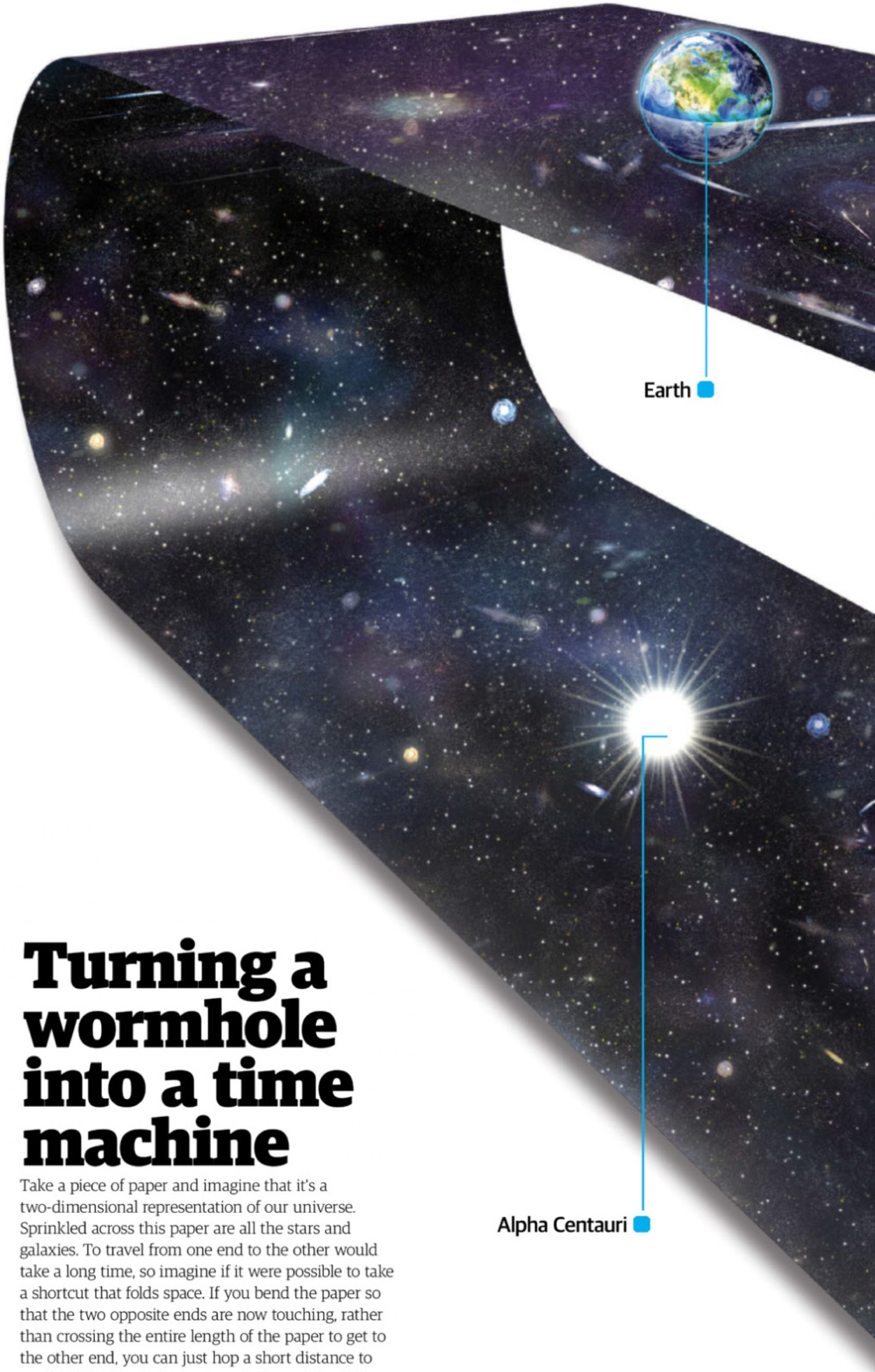
Stephen Hawking doesn't think it's possible to travel through a wormhole, even after capturing and enlarging one. He's concerned about time-travel paradoxes and uses the Mad Scientist Paradox as an example. Here a scientist creates a wormhole in his lab that takes him back ten minutes in time. Seeing himself ten minutes ago he shoots himself dead. Yet if he's dead in the past, how can he be alive in the future to shoot himself?

Uncertainty

Stephen Hsu and Roman Buniy of the University of Oregon suggested the uncertainty principle of quantum mechanics, stating that the more precisely a property of a particle is known, the less precisely other properties can be known. As wormholes involve quantum effects, Hsu and Buniy claim you can never know exactly where you will end up once you travel through the wormhole.

Interstellar

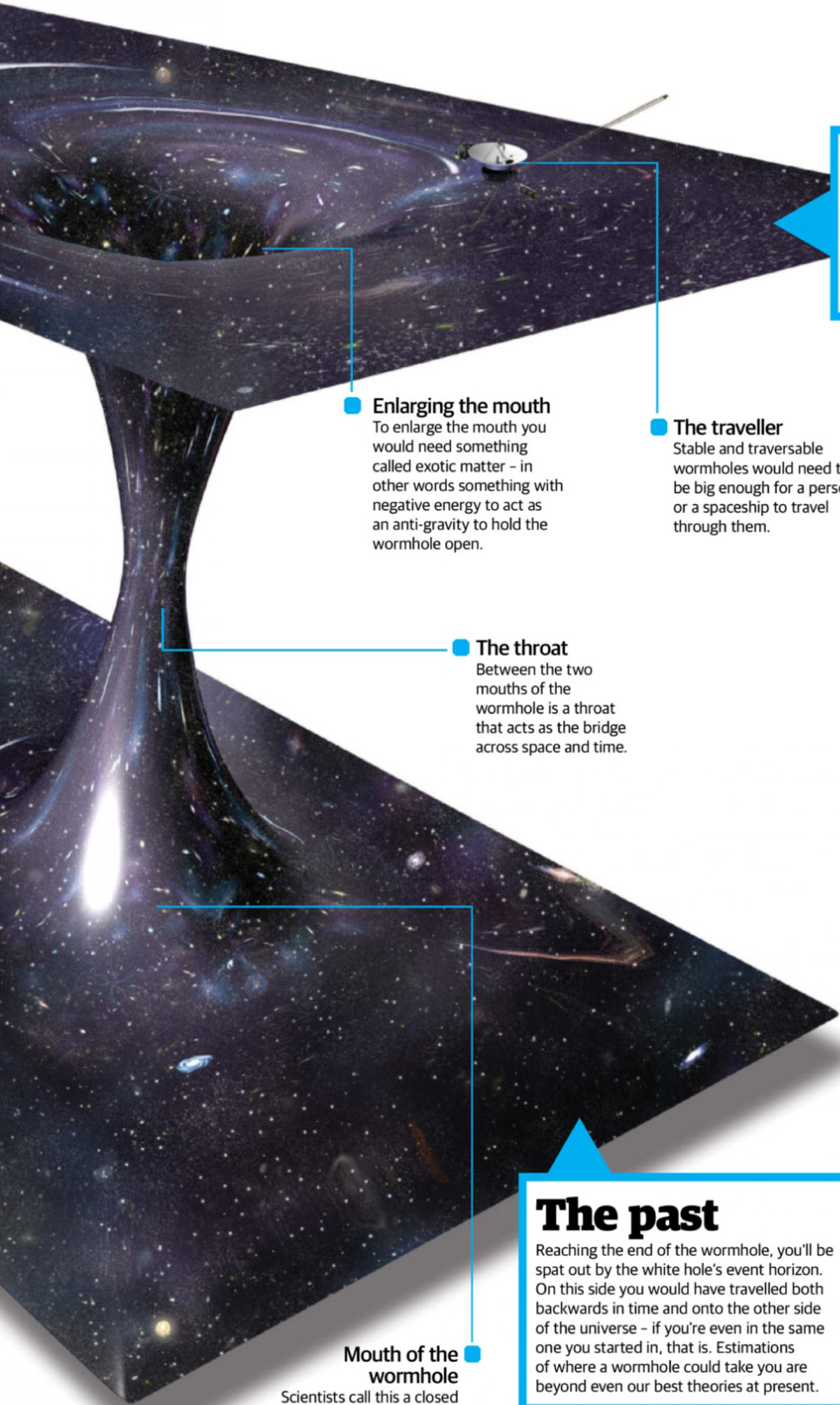
Kip Thorne's theories will feature in a new Hollywood blockbuster that he's co-producing called *Interstellar*, which will involve travel through a wormhole and will be released this November. Thorne himself is no stranger to science fiction – when Carl Sagan needed a means of faster-than-light space travel for his novel *Contact*, Thorne developed the science behind wormholes that Sagan could then use in his story.



Turning a wormhole into a time machine

Take a piece of paper and imagine that it's a two-dimensional representation of our universe. Sprinkled across this paper are all the stars and galaxies. To travel from one end to the other would take a long time, so imagine if it were possible to take a shortcut that folds space. If you bend the paper so that the two opposite ends are now touching, rather than crossing the entire length of the paper to get to the other end, you can just hop a short distance to reach it. The idea is that a wormhole would act like a bridge to connect the two ends together.

Now imagine that the paper doesn't just represent space, but also time. This means that a wormhole doesn't just connect two different spaces within the universe, but can also connect two time periods. This accompanying diagram illustrates exactly how this could be possible.



The present

Your starting point can be at any place or any time where the wormhole mouth is found. This can be formed by violent events in the universe, such as colliding gravitational waves produced by high-velocity cosmic rays.

Enlarging the mouth
To enlarge the mouth you would need something called exotic matter – in other words something with negative energy to act as an anti-gravity to hold the wormhole open.

The traveller
Stable and traversable wormholes would need to be big enough for a person or a spaceship to travel through them.

The throat
Between the two mouths of the wormhole is a throat that acts as the bridge across space and time.

Mouth of the wormhole
Scientists call this a closed time-like curve – a loop that connects the two different periods of time found at each mouth of the wormhole.

The past

Reaching the end of the wormhole, you'll be spat out by the white hole's event horizon. On this side you would have travelled both backwards in time and onto the other side of the universe – if you're even in the same one you started in, that is. Estimations of where a wormhole could take you are beyond even our best theories at present.

Space Observatory, but Spektr-R, a radio telescope that launched into space in 2011 and has a detector diameter of ten metres (33 feet). The hope is that with Spektr-R they will finally discover evidence for wormholes and white holes.

The project's initial steps into probing the universe were originally quite bleak, because the Soviet Union collapsed just as it was within reach of being completed, but now it has been restarted. Until quite recently an old radio telescope built in 1959, dubbed RT-22, was the main receiver of signals from the Spektr-R. For many months the receiver has been studying supermassive black holes found at the centres of galaxies and even probing the Milky Way's own black hole, Sagittarius A*. Observations of the black hole's event horizon – the point of no return from this exotic high-gravity beast – is where RadioAstron's aims get interesting.

Getting close to black holes could lead us to the elusive wormholes and white holes, according to RadioAstron scientists. The trick is to keep our eyes peeled for a certain signature. "We must look for the structure of magnetic fields near the centres of galaxies," says Novikov, who back in 1964 also pointed out that general relativity allows for the existence of white holes. "If the structures of the magnetic fields appear to be magnetic monopoles, that are macroscopic in size, then this is a wormhole. [These magnetic phenomena have only one pole and are predicted to exist but so far, like wormholes, have proven elusive]." It turns out that wormholes – specifically their white holes – will emit their own radiation, in contrast with black holes that don't emit radiation themselves, but rather intensive radiation from the surrounding gas that spews out in swirls.

"We should always look out for what's out there, however, I wouldn't hold my breath"

Professor Andreas Karch, University of Washington

We might not have detected a wormhole for sure, but it turns out RadioAstron might be on to something. Turning its attention to the core of quasar 3C273, in the constellation Virgo around 2.5 billion light years away, it has found something unexpected. Quasars are active galactic nuclei producing enormous amounts of radiation from around their black holes. We know there's a black hole in the heart of 3C273, but RadioAstron's observations show that it has increased in temperature. There's also the weird and wacky magnetic field that Novikov mentioned earlier, so RadioAstron must keep looking to verify the increasing suspicions of theoretical physicists.

Meanwhile, instead of using telescopes to scan the skies for these elusive tunnels, other astrophysicists have taken to imagining wormholes. For example, take the work of theoretical physicists Jensen and Karch, who have suggested that the particles of a quantum phenomena called entanglement are connected by miniature wormholes. When two particles interact they can become entangled so that their characteristics correlate. The famous Heisenberg Uncertainty Principle means that the quantum states, or properties of the particles such as their spin, remain undefined until they're measured properly. However, when the spin of one of the entangled particles is measured, then the other particle instantly follows suit, even if each of them are on opposite sides of the universe at the time.

How they communicate across huge distances so quickly is not truly understood, but Karch and Jenson have proposed that tiny black holes that have become entangled may have wormholes connecting them. Julian Sonner, of the Massachusetts Institute of Technology, has taken this idea a step further, showing that wormholes could connect entangled quarks, which are the fundamental particles that make up protons and neutrons inside of atoms.

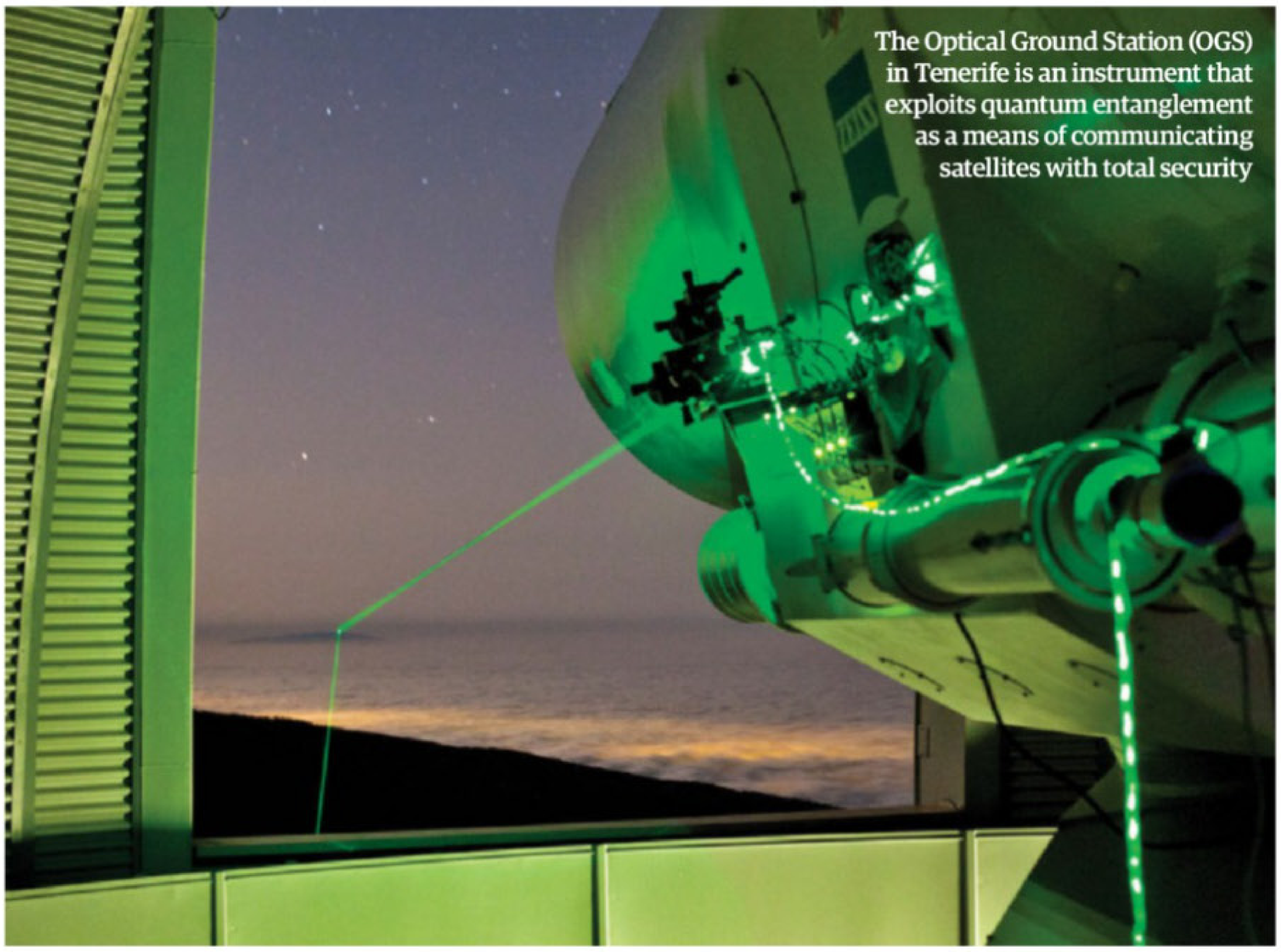
Another place where theorists are looking for wormholes is inside stars themselves, although their location might make it a little bit difficult for us to reach them. Vladimir Folomeev of the Institute of Physicotechnical Problems and Material Science in the Kyrgyz Republic (Kyrgyzstan) has suggested that if exotic phantom matter exists – the same kind of stuff as dark energy, which has negative energy density – then it's possible it could exist within stars.

"The idea is very simple," explains Folomeev. "If dark energy amounts to about 70 per cent of the total energy density of the universe, then it is natural to assume that in some cases mixed objects consisting of both ordinary matter and dark energy can exist." A mixed star would act oddly, affecting the star's mass and causing unusual oscillations as the negative energy phantom matter moves around inside the star.

There are many places that wormholes could be hiding, from inside black holes and stars, to the subatomic world, but the big question is, what would it be like to travel down one? According to Davis, the mouth would look like a sphere with a distorted mirror image of the region of space on the other side of the wormhole, as the negative energy density deflects light passing through. When you pass through, the journey would likely be instantaneous and looking back you'd see another sphere reflecting where you came from. Across the universe in a single step – wormholes would be a truly giant leap. ■

An artist's impression of quantum entanglement. If two photons of light are allowed to properly interact with each another, they can become entangled

> "When you pass through, the journey would be instantaneous"



The Optical Ground Station (OGS) in Tenerife is an instrument that exploits quantum entanglement as a means of communicating satellites with total security

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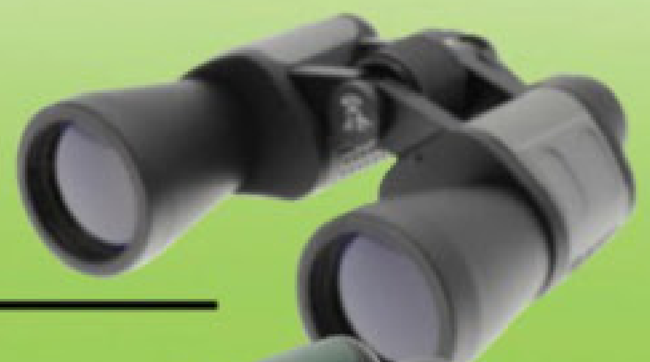

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Giant Moon crater

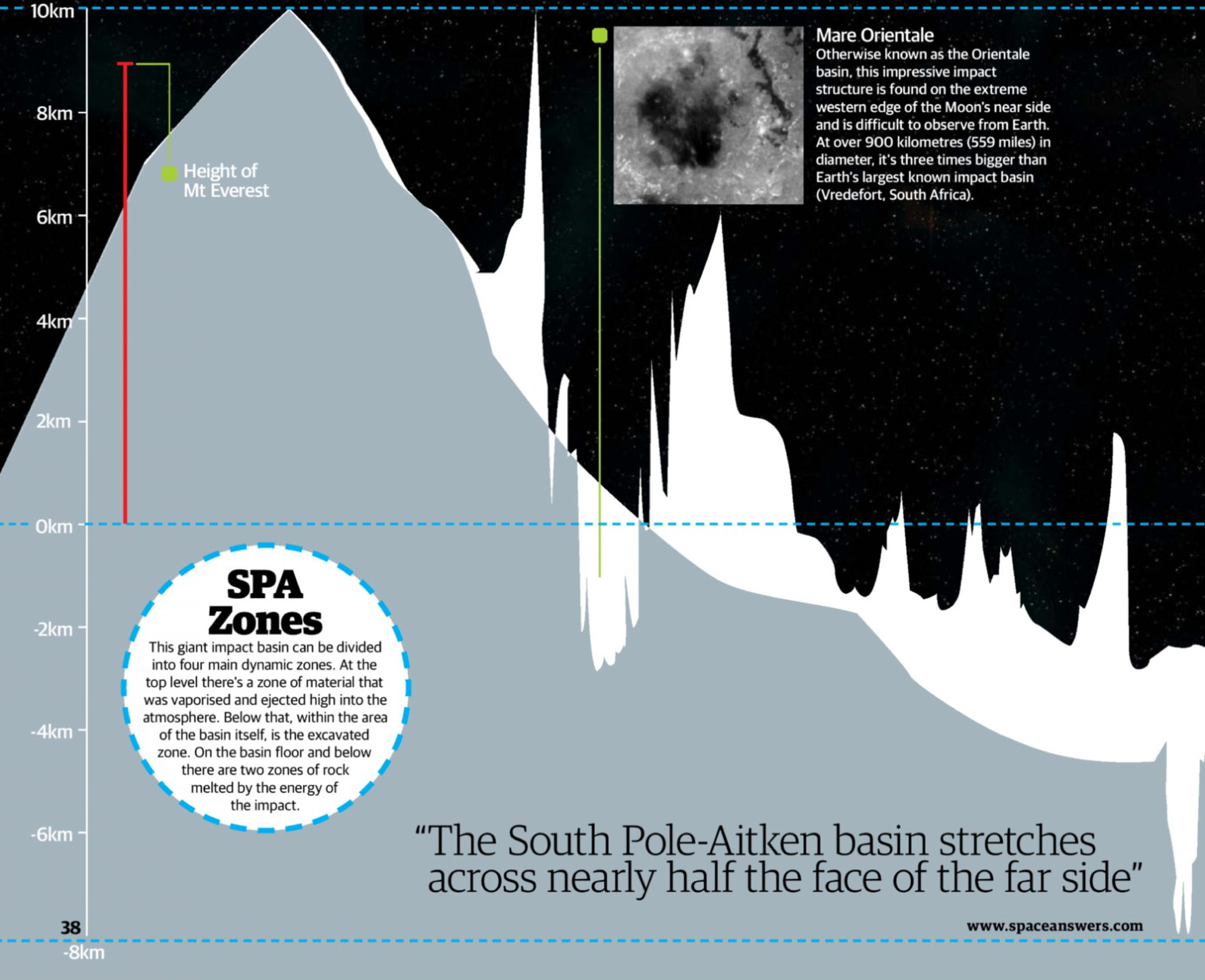
It's one of the biggest impact structures in the Solar System and we can't even see it from Earth, so what is the South Pole-Aitken basin hiding?

Since prehistory and up until the middle of the 20th century we've only ever seen one side of the Moon. The unfaltering synchronisation of its 27.3-day orbit and axial spin means the same dark maria and the ray system of its distinctive impact crater, Tycho, are among the only lunar features we'll ever be able to see from Earth. However, fringing the lunar South Pole is a range of particularly tall mountains – an excruciating hint to pre-space-age astronomers that there was a very interesting and large feature just out of sight.

It wasn't until the lunar fly-by of a Soviet probe in October 1959 that we got our first glimpse of the far side of the Moon and what this feature was. The 29 photos Luna 3 returned were fuzzy but showed a different landscape to the familiar near hemisphere, including a basin-like structure. Following NASA's 1966-1967 Lunar Orbiter program that mapped 99 per cent of the Moon's surface, the enormous scale of this structure soon became apparent.

The South Pole-Aitken (SPA) basin is named after two geographical objects that mark either end of its north-south borders: the lunar South Pole and the Aitken crater. SPA stretches across nearly half the face of the Moon, around 2,500 kilometres (1,550 miles) in diameter, and its depth is equally impressive at around 13 kilometres (eight miles) from the bottom of the basin to its north-east peak. These dimensions make it one of the biggest confirmed impact basins in the Solar System and it's the oldest too, at 3.9 billion years old.

The impact that created SPA would have been colossal. An asteroid of around 170 kilometres (105



Mare Orientale
Otherwise known as the Orientale basin, this impressive impact structure is found on the extreme western edge of the Moon's near side and is difficult to observe from Earth. At over 900 kilometres (559 miles) in diameter, it's three times bigger than Earth's largest known impact basin (Vredefort, South Africa).

SPA Zones

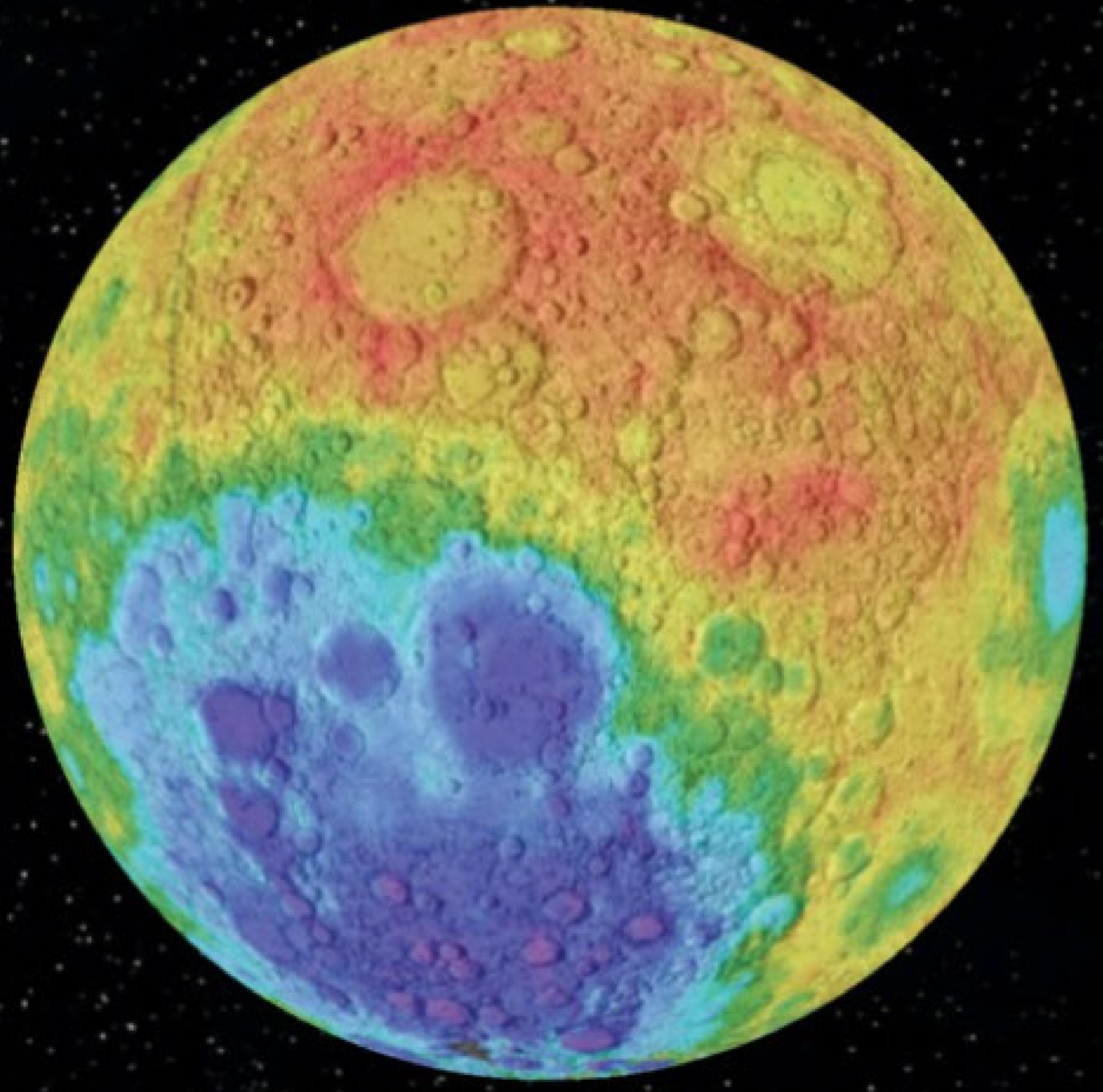
This giant impact basin can be divided into four main dynamic zones. At the top level there's a zone of material that was vaporised and ejected high into the atmosphere. Below that, within the area of the basin itself, is the excavated zone. On the basin floor and below there are two zones of rock melted by the energy of the impact.

> "The South Pole-Aitken basin stretches across nearly half the face of the far side"

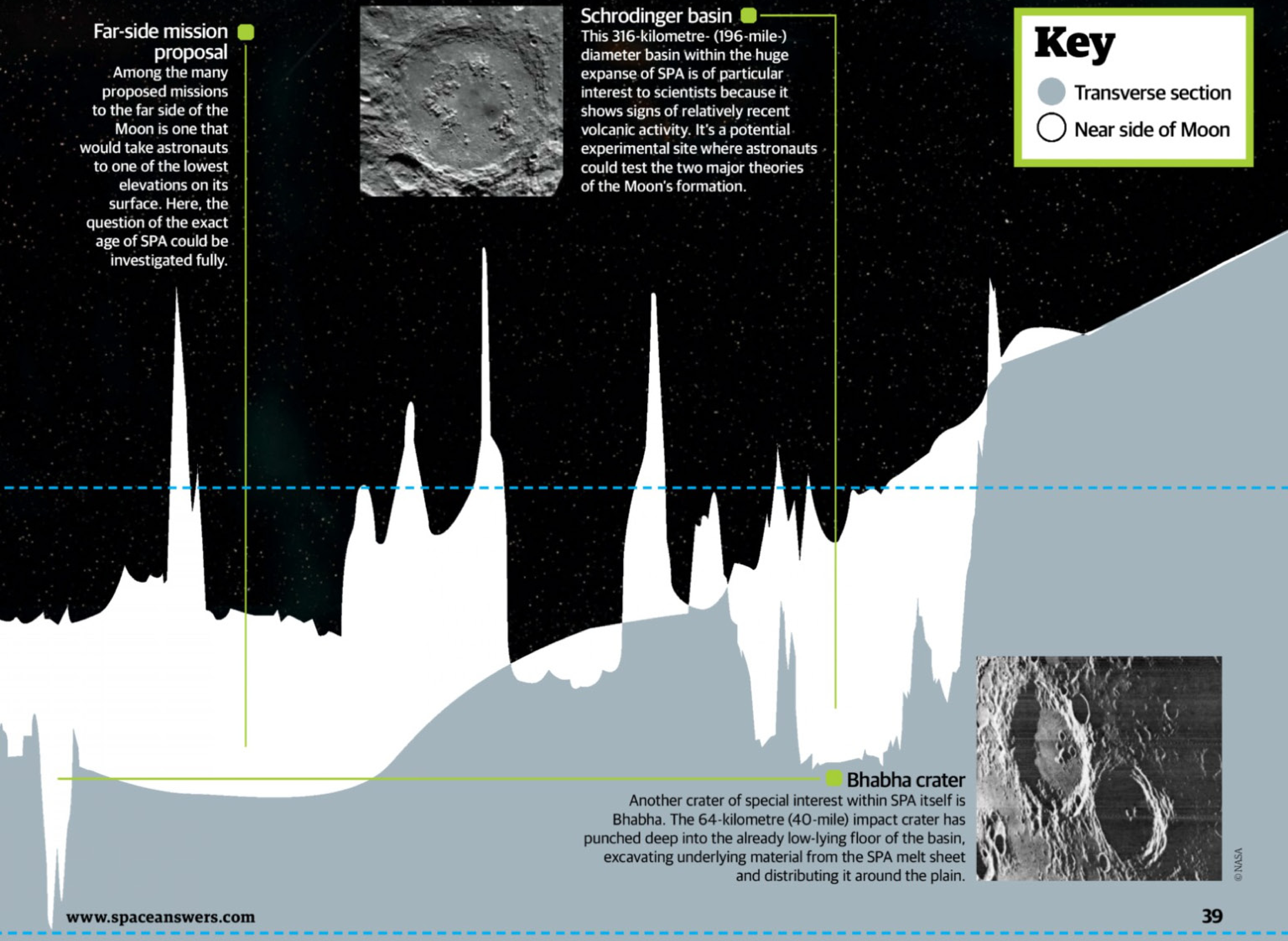
miles) in diameter, travelling at around 40,000 kilometres (24,854 miles) per hour smashed into the surface, changing the shape of the Moon so that it still bulges on the near side today. It also distributed a huge mass of ejecta that blankets the lunar globe. Simulations show that this impact was so energetic that the lava in the mantle beneath the Moon's crust would have been exhumed and, following the central uplift, thrown nearly 1,000 kilometres (621 miles) high before collapsing back to the surface. Giant melt sheets are characteristic of such huge impacts and the energy that the asteroid transferred to the Moon liquefied the rock in the region.

SPA is scientifically significant because, as the oldest impact crater on the Moon, it's a starting point for what could be a critical event in the Solar System. We know that this basin, as well as most of the other impact basins on the Moon, was formed during an era called the Late Heavy Bombardment period. Scientists want to know exactly how old SPA is because most of the larger objects left over from the birth of the Solar System accreted into the rocky inner planets, so only unusual gravitational dynamics could have caused a spike in the rate of impacts, peppering the Moon with so many craters. In this case there may have been a cataclysmic event that affected all the inner planets of the Solar System, bombarding them with giant space rocks. If SPA is much older than 3.9 billion years old, it means that the impact rate is simply a gradual decline from an earlier, more-violent time.

Sampling some of the rock from inside the basin is the best way of nailing down the exact age of SPA, although it's so big and so old that it's been subject to hundreds of impacts since, resetting the age of some of the surrounding rock for radiometric purposes. Regardless, SPA has been proposed as the site for several lunar sample-and-return missions in the near future. It's also been put forward as a location for an enormous far-side radio telescope.



Topographical image of the Moon showing high ground in red and low in blue. The size and depth of the SPA impact basin is clearly seen



Far-side mission proposal

Among the many proposed missions to the far side of the Moon is one that would take astronauts to one of the lowest elevations on its surface. Here, the question of the exact age of SPA could be investigated fully.

Schrodinger basin

This 316-kilometre- (196-mile-) diameter basin within the huge expanse of SPA is of particular interest to scientists because it shows signs of relatively recent volcanic activity. It's a potential experimental site where astronauts could test the two major theories of the Moon's formation.

Bhabha crater

Another crater of special interest within SPA itself is Bhabha. The 64-kilometre (40-mile) impact crater has punched deep into the already low-lying floor of the basin, excavating underlying material from the SPA melt sheet and distributing it around the plain.

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10 INTREPID FUTURE LANDERS

Innovative machines that could enable us to explore the cosmos like never before

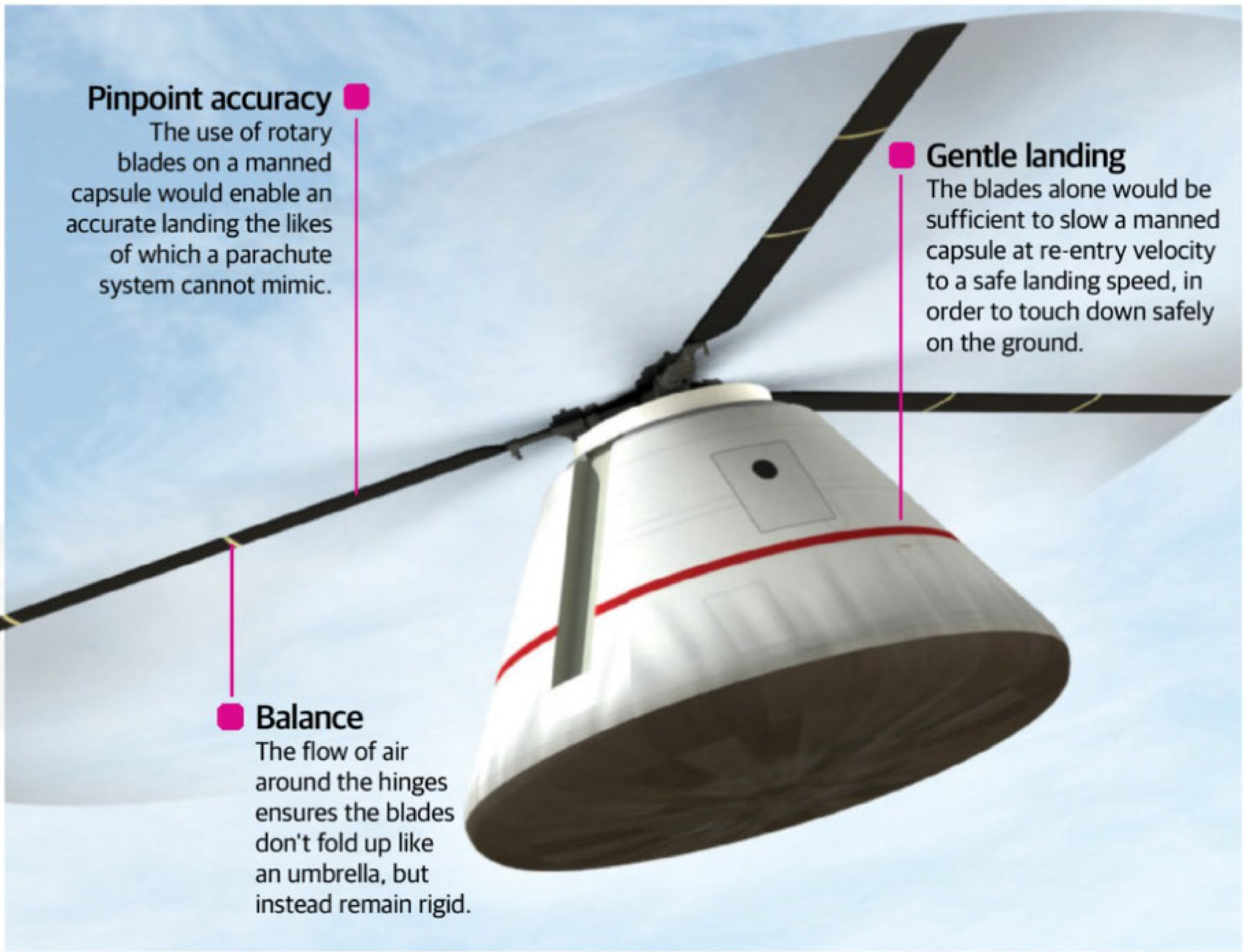
Written by Jonathan O'Callaghan

Landing spacecraft on other worlds in the Solar System, or even our planet, is not an easy business. On Earth you have to contend with a thick atmosphere coupled with a relatively strong gravitational pull when compared with elsewhere. When tackling distant worlds there's also the small matter of getting there in the first place before attempting to traverse unchartered terrain.

While we have tried and tested many methods to land spacecraft, from parachutes on Earth to the Sky Crane employed by NASA to land Curiosity on Mars, many of these methods limit what sort of spacecraft or vehicle we can land.

When it comes to places like Europa, we just don't have a means of reaching its subsurface ocean. Researchers and scientists have been busy designing new contraptions that could bring about multiple revolutions in landing technology, so here we've taken a look at ten of the most exciting innovations that could be heading our way in the near future.

SPACEX
DRAGON


Pinpoint accuracy
The use of rotary blades on a manned capsule would enable an accurate landing the likes of which a parachute system cannot mimic.
Gentle landing
The blades alone would be sufficient to slow a manned capsule at re-entry velocity to a safe landing speed, in order to touch down safely on the ground.
Balance
The flow of air around the hinges ensures the blades don't fold up like an umbrella, but instead remain rigid.

1 Roto Capsule

Landing capsules with parachutes could be a thing of the past if this promising technology comes to fruition. Researchers at NASA have been looking into the possibility of using rotary blades, akin to those found on a helicopter to safely return a manned capsule to a precision landing on Earth, instead of the rather less-precise landings offered by parachutes.

These rotors are slightly different from helicopter blades, however. They aren't powered, but instead use the passing wind to turn in a process known as auto-rotation. This method has been tried and tested on helicopters, but it has never been applied to a vehicle returning from space.

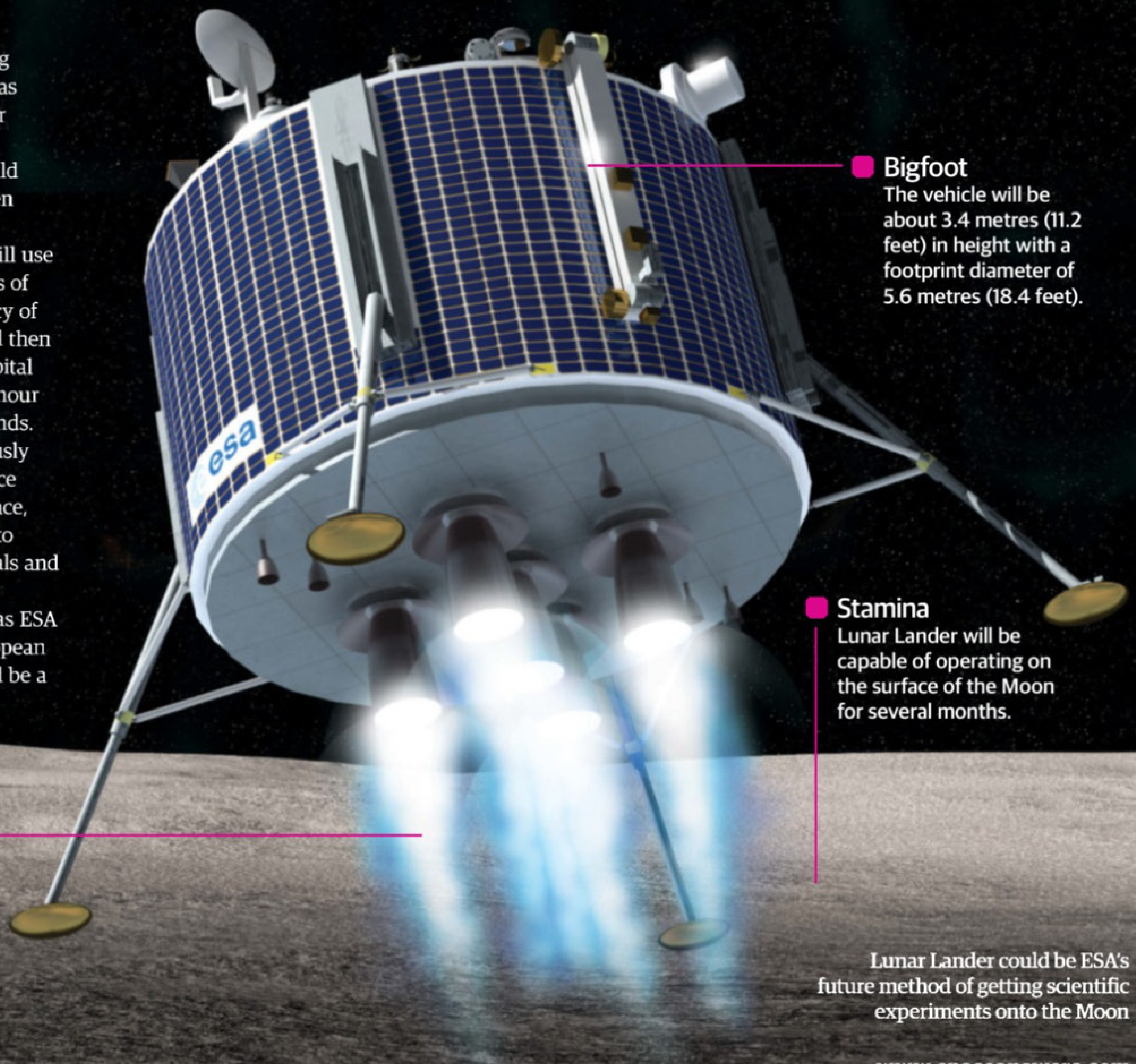
Engineers at NASA's Johnson Space Center have now tested a scale model of this innovative concept, successfully dropping a 0.9-kilogram (two-pound) capsule from 146 metres (480 feet) onto the floor. The ultimate goal is to enable a full-scale system to employ the technology and land accurately at any location in the world. The same concept could also be applied to spent rocket boosters, bringing them safely to Earth to be used again on another launch.

2 Lunar Lander

This robotic explorer is ESA's answer to landing scientific experiments on the Moon, intended as a forerunner to human exploration of the lunar surface. ESA first recognised the need for an accurate, safe and autonomous lander that could take a significant payload to the Moon and then designed a vehicle accordingly.

Dubbed simply Lunar Lander, the vehicle will use an optical navigation system to process images of the lunar surface and ensure a landing accuracy of just a few hundred metres. Its 27 thrusters will then manoeuvre the vehicle and slow it from an orbital velocity of 6,000 kilometres (3,728 miles) per hour down to just a few kilometres per hour as it lands. All of these decisions will be made autonomously by Lunar Lander, with no input from Earth once the landing sequence is triggered. On the surface, Lunar Lander will have a host of instruments to study the Moon, such as investigating chemicals and identifying their use for future missions.

For now this concept is on the back-burner as ESA focuses on other goals, but for any future European Moon mission it's likely that Lunar Lander will be a prime candidate.


esa
Bigfoot
The vehicle will be about 3.4 metres (11.2 feet) in height with a footprint diameter of 5.6 metres (18.4 feet).
Stamina
Lunar Lander will be capable of operating on the surface of the Moon for several months.
Power landing
Its 27 thrusters will enable the vehicle to get from lunar orbit to the Moon's surface in one piece.

Lunar Lander could be ESA's future method of getting scientific experiments onto the Moon

3

Reusable rockets

For decades we've relied on expendable rockets to reach space, with the boosters and tanks being disposed of on almost every occasion once their payload had reached orbit. It's a costly endeavour and one that SpaceX hopes to rectify with a revolutionary concept that could dramatically alter the launcher business and drastically reduce the cost of sending payloads into space. SpaceX is hoping to make rockets reusable so that everything launched can be recovered and used again on subsequent launches. For now it's only looking at returning the first stage of a rocket, but in the future it may be possible to return an entire rocket to Earth to be used for another launch.

The American company has been designing this so-called Grasshopper rocket technology for years by means of small hops off the ground, testing the possibility of using a controllable booster to return rockets to Earth after launch to be used again. Now it's nearing the point where this same technology can be tested on a fully fledged launch rather than the small jumps it has performed so far, but just how does it work? Take a look at our illustration to see how SpaceX plans to bring rockets back from the abyss.

> "In the future it may be possible to return an entire rocket to Earth"

Launch
The Falcon 9 rocket lifts off as usual, burning its nine Merlin 1D engines for 180 seconds to reach the required orbit.

Separation
After 180 seconds the second stage, carrying a payload such as the Dragon capsule, separates from the first stage.

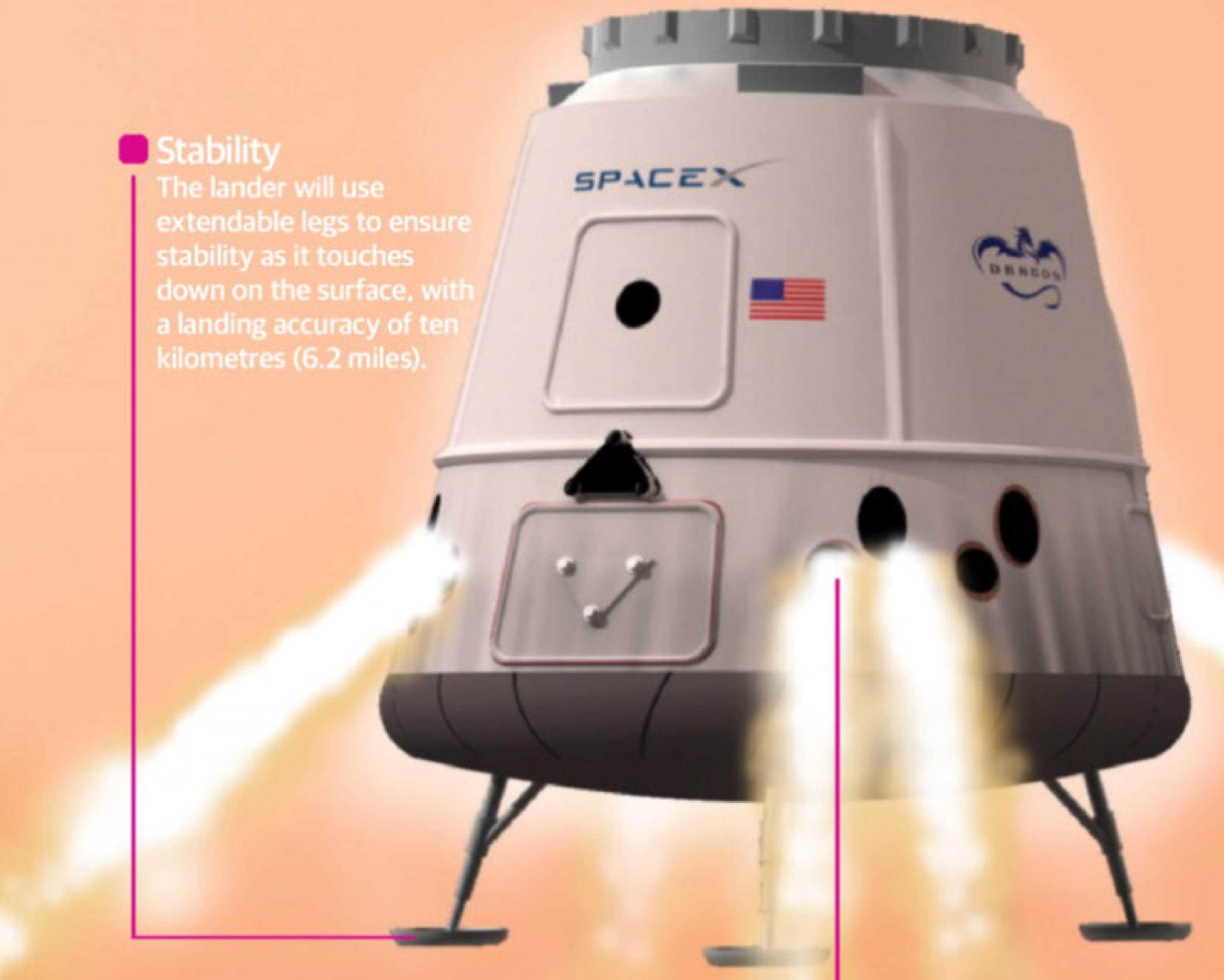
Orientation
A cold gas attitude control system reorients the rocket so its engine is now facing forwards and three engines ignite so that it survives re-entry.

Descent
The rocket's low centre of gravity, coupled with aerodynamic legs, ensures it remains stable as it descends, with the engines reducing its speed.

Carefully does it
A few tens of metres above the ground, the engines ignite once more to bring the rocket to a safe and stable landing in a specified area close to where it launched.

TOUCH DOWN ON THE RED PLANET

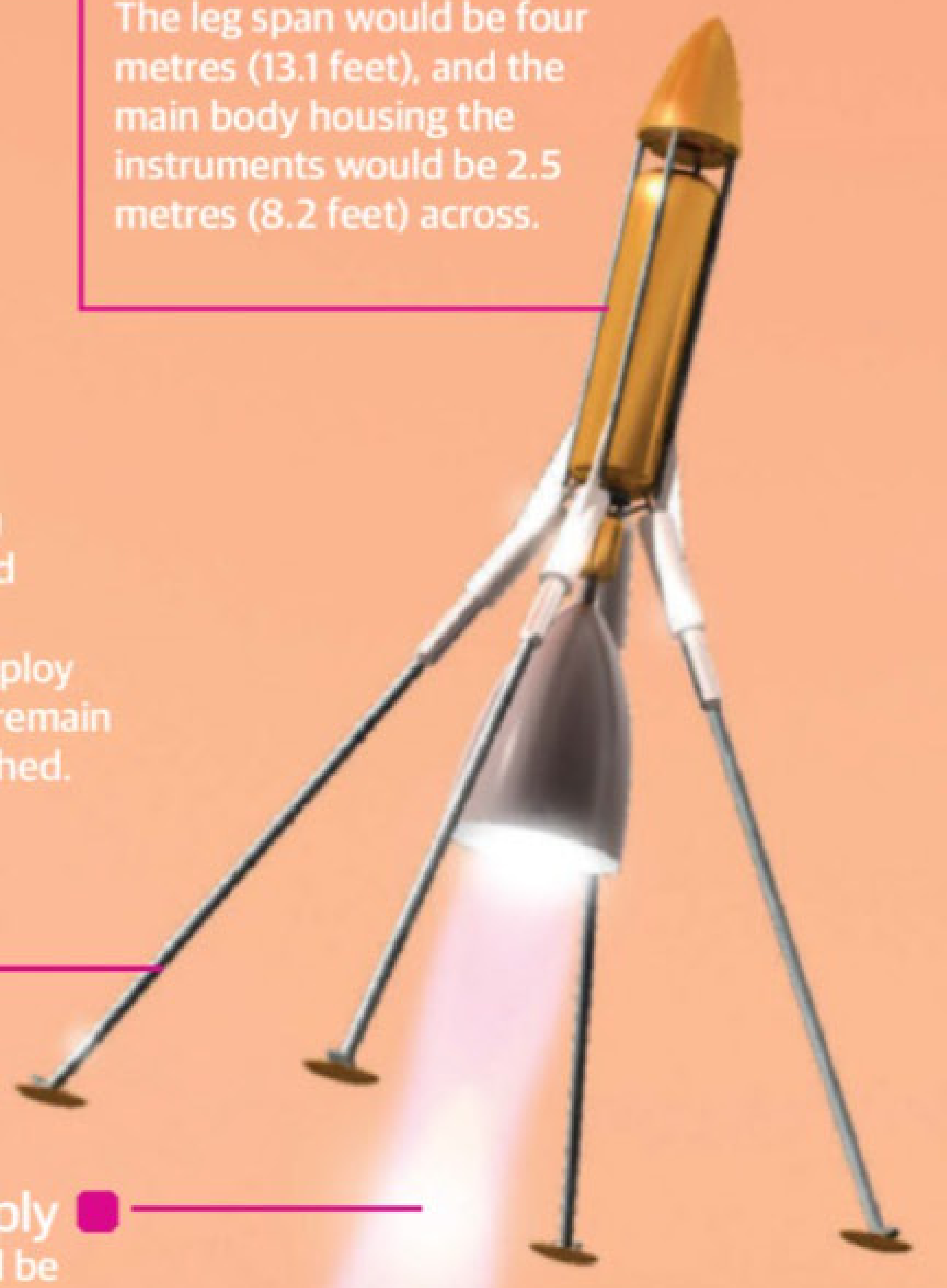
Some revolutionary designs for conquering Mars



Stability
The lander will use extendable legs to ensure stability as it touches down on the surface, with a landing accuracy of ten kilometres (6.2 miles).

Retrorockets
Red Dragon will land without parachutes, instead using a combination of drag from the Martian atmosphere and retro-propulsion thrusters to safely touch down on the surface.

Exclusive access
The use of thrusters will enable Red Dragon to touch down at sites inaccessible to vehicles using parachutes, such as areas of high elevation.



Big stride
The entire hopper would weigh about 1,000 kilograms (2,205 pounds). The leg span would be four metres (13.1 feet), and the main body housing the instruments would be 2.5 metres (8.2 feet) across.

Strong legs
In order to cope with the strain of repeated leaps, the legs of the Mars Hopper will employ magnets in order to remain rigid and not be crushed.

Infinite supply
Carbon dioxide could be gathered from the Martian atmosphere to be used as a propellant inside the vehicle, in order to jump to different destinations.

4 Red Dragon

Landing humans on the surface of Mars is something that is surely still decades away, but SpaceX has already begun to plan how it or another space-exploratioinon agency might be able to perform the feat.

The concept spacecraft is the Red Dragon, a modified variant of the Dragon capsule that has already successfully flown unmanned into Earth orbit and back. The capsule itself is rather spacious at 3.7 metres (12.1 feet) in diameter, with an interior volume of 11 cubic metres (388 cubic feet). Upon entering the Martian atmosphere, the capsule would use powerful retrorockets to slowly and safely lower itself to the surface without damaging the instruments or humans inside.

If a Red Dragon is one day sent to Mars, it's likely the first will be unmanned to test the technology, merely carrying instruments to be used on the surface of Mars, including a drill. For a future manned mission, this could be the vehicle that takes humans to the surface, although of course it would need to be accompanied by other vehicles, perhaps more Red Dragons, that would bring additional cargo and liveable habitats to the surface.

5 Hopper

Once you've landed on Mars, you're kind of stuck in that area, right? Well, what if you could take off and land again and again?

That's exactly what a team from the UK's Leicester University and the Astrium space company have envisioned, which they've dubbed the Mars Hopper. This lander would acquire propellants from the Martian atmosphere as it passed through, enabling it to perform hops of as much as a kilometre (0.62 miles) on the Martian surface.

Once on the ground, carbon dioxide from the air is compressed and liquefied, before being pumped into a chamber and exposed to intense heat from a radioactive source. This carbon dioxide would then explosively expand and could be fired out of a nozzle to propel the vehicle into the air again to repeatedly land in several different locations.

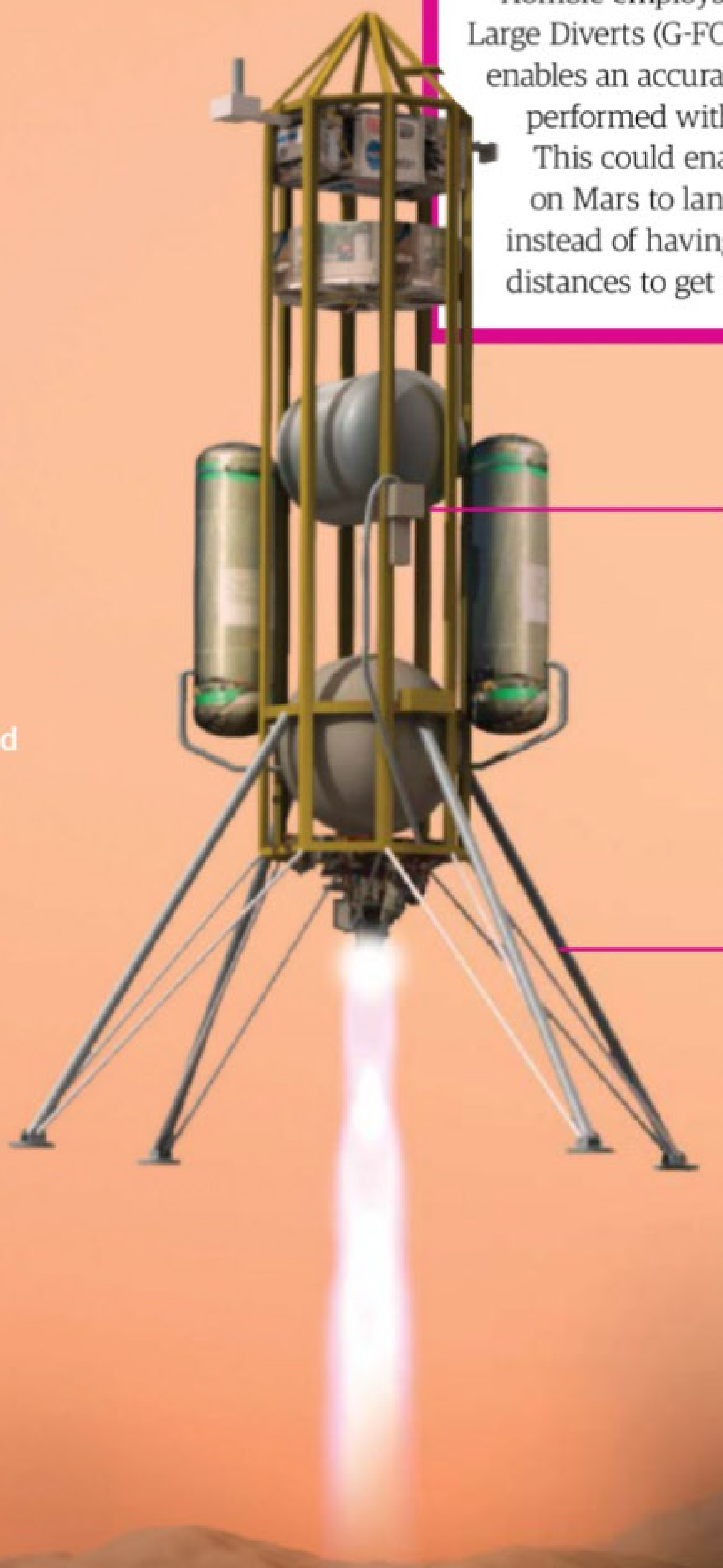
The benefits of such a technology are obvious; the Mars Hopper could leap across the surface, exploring many different locales of interest in a short amount of time, rather than confining itself to the landing site it initially touched down in.

6 Xombie

One of the biggest obstacles to landing on an alien world is accuracy. A lander needs to avoid potential obstacles such as rocks and craters, and it also needs to be able to touch down in a targeted area.

When NASA's Curiosity rover landed on Mars in August 2012, it had a radial landing accuracy of several kilometres, but Masten Space Systems' Xombie technology could significantly improve this accuracy six-fold using an innovative design.

Xombie employs Guidance for Fuel Optimal Large Diverts (G-FOLD), which in basic terms enables an accurate landing to be calculated and performed with only limited amounts of fuel. This could enable future robotic missions on Mars to land closer to features of interest, instead of having to drive extremely long distances to get to them.



Planetary options
The Xombie landing technology would enable spacecraft to land on other worlds such as Mars, with accuracy as refined as a several hundred-metre radius.

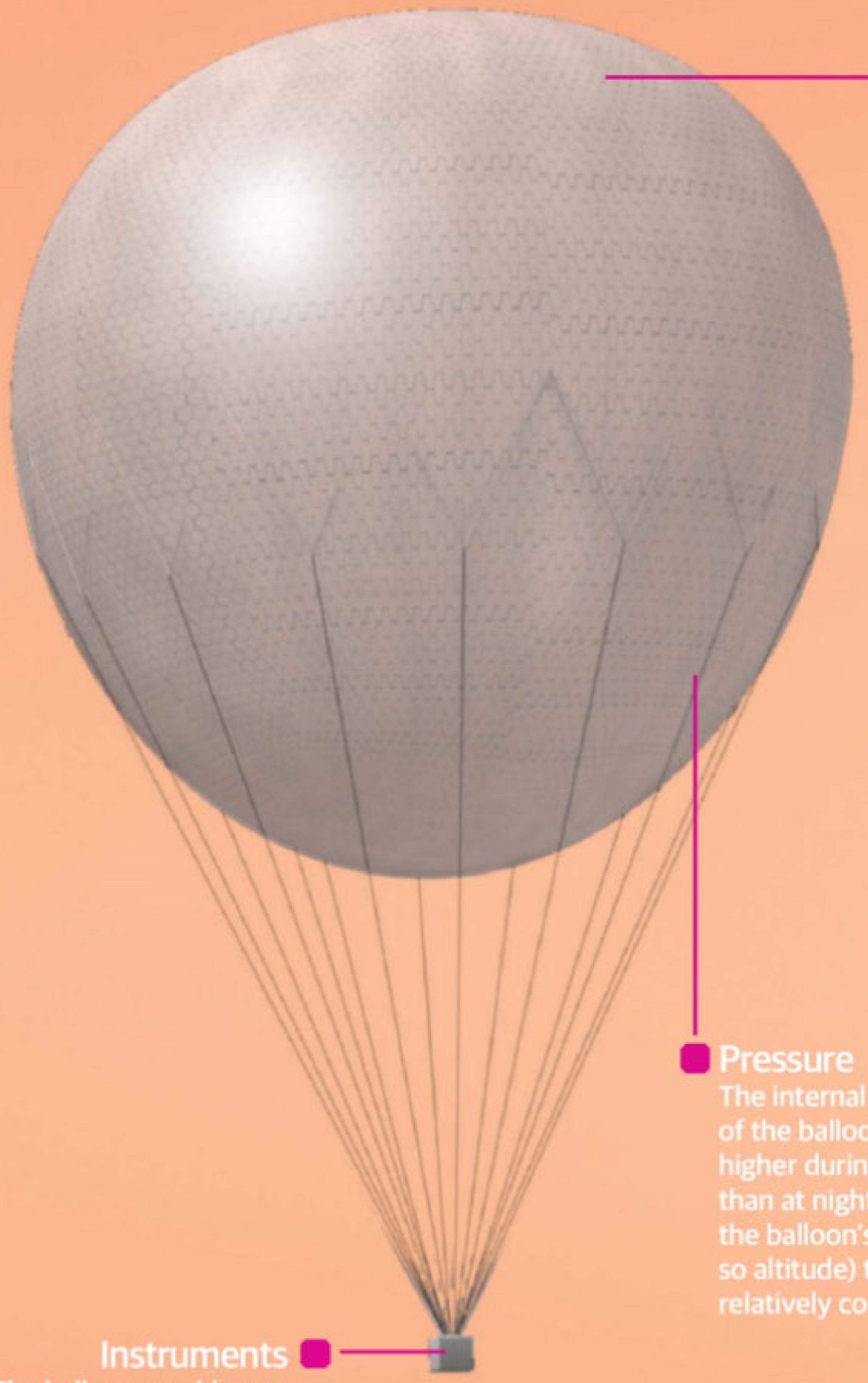
Points of interest
Such an accurate landing could enable future robotic missions to land much closer to points of interest, rather than having to spend time driving to them.

7 Shielded Mars Balloon Launcher

Using balloons to travel above the surface of Mars in order to study the planet has long been of interest, but exactly how to get the balloon there has been a conundrum. This particular technology, the Shielded Mars Balloon Launcher (SMBL), could be the answer.

Rather than putting a balloon directly into the Martian sky, this compact lander would touch down on the surface likely using parachutes. There, a structure would be extended and in it a balloon would be inflated. Attached to the base of the balloon would be an instrument package that would be carried into the sky in order to carry out tests from the air.

The proposed SMBL system is small enough, at a mass of just 15 kilograms (33 pounds), that it could piggyback as a secondary payload on a larger Mars mission.



Blown up
Once on the surface, the balloon would be inflated inside the lander on the surface and, when the required volume was reached, it would be released into the Martian sky.

Pressure
The internal pressure of the balloon would be higher during the day than at night, enabling the balloon's volume (and so altitude) to remain relatively constant.

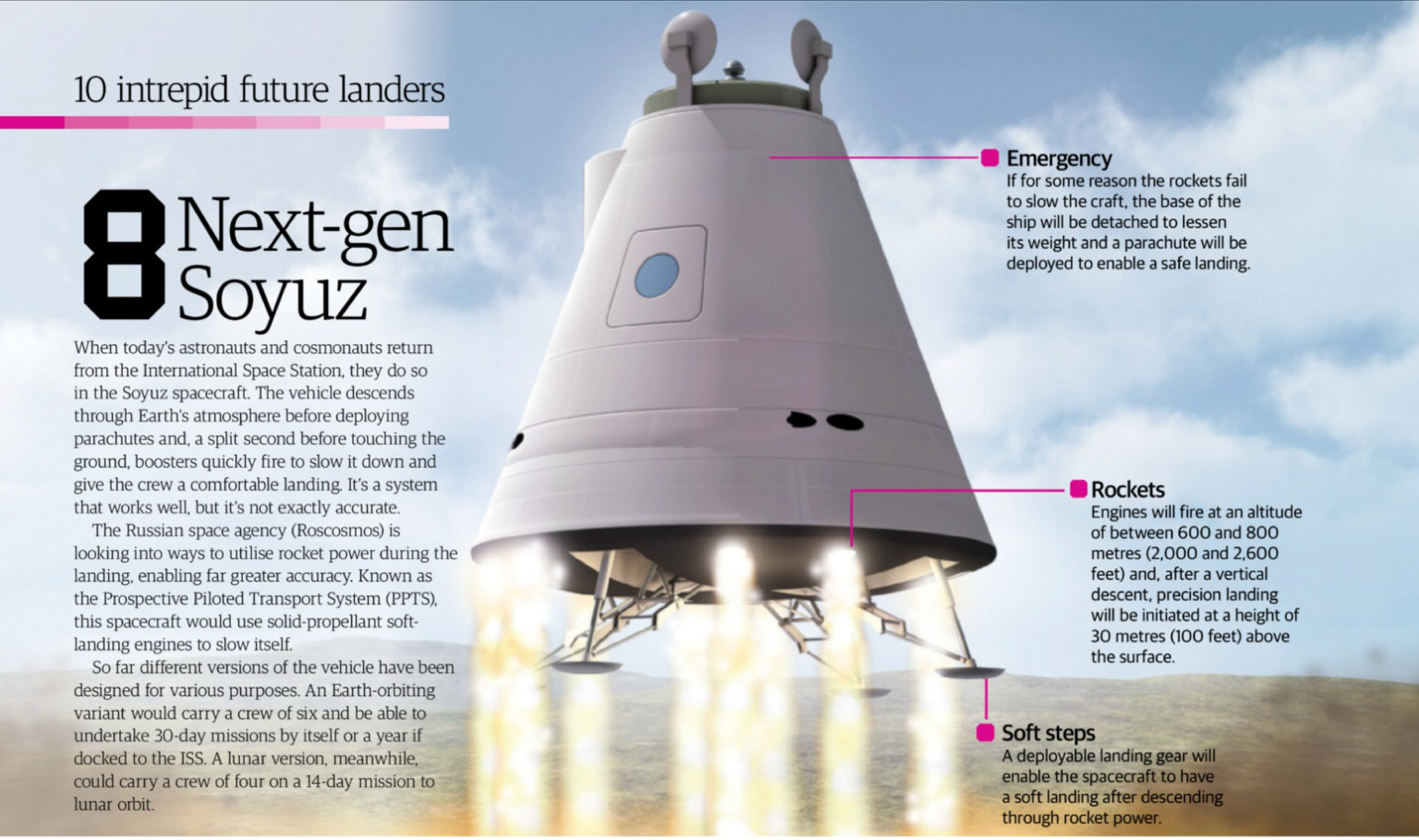
Instruments
The balloon would carry several instruments to perform advanced studies that cannot be replicated on the ground, including cameras, magnetometers and spectrometers.

8 Next-gen Soyuz

When today's astronauts and cosmonauts return from the International Space Station, they do so in the Soyuz spacecraft. The vehicle descends through Earth's atmosphere before deploying parachutes and, a split second before touching the ground, boosters quickly fire to slow it down and give the crew a comfortable landing. It's a system that works well, but it's not exactly accurate.

The Russian space agency (Roscosmos) is looking into ways to utilise rocket power during the landing, enabling far greater accuracy. Known as the Prospective Piloted Transport System (PPTS), this spacecraft would use solid-propellant soft-landing engines to slow itself.

So far different versions of the vehicle have been designed for various purposes. An Earth-orbiting variant would carry a crew of six and be able to undertake 30-day missions by itself or a year if docked to the ISS. A lunar version, meanwhile, could carry a crew of four on a 14-day mission to lunar orbit.



Emergency
If for some reason the rockets fail to slow the craft, the base of the ship will be detached to lessen its weight and a parachute will be deployed to enable a safe landing.

Rockets
Engines will fire at an altitude of between 600 and 800 metres (2,000 and 2,600 feet) and, after a vertical descent, precision landing will be initiated at a height of 30 metres (100 feet) above the surface.

Soft steps
A deployable landing gear will enable the spacecraft to have a soft landing after descending through rocket power.

9 Europa Submarine

When it comes to landing on other worlds in the Solar System, most require some vehicle capable of traversing a hard surface. Most, that is, apart from Europa, where there is believed to be a vast subsurface ocean containing more water than on the entire Earth, just waiting to be explored.

Various proposals have been drawn up to explore this underground ocean and one of the most exciting is a submersible vehicle that could journey under the ice, sending data back to its parent spacecraft. A submarine, such as one devised by professor Carl Ross at the University of Portsmouth in England, would need to be able to withstand the expected high pressures from the deep oceans, some as much as 100 kilometres (62 miles) deep, ten-times deeper than any oceanic trench on Earth. It would also need a fuel cell to power its propulsion systems in addition to its communications and scientific instruments.

The goal of the mission would be to discern if Europa's oceans harbour life, or at least have the potential to do so. Of course, such a mission is still decades away from coming to fruition, but perhaps our first vehicle to venture beneath Europa's icy surface will not be too dissimilar from this.

> "The goal of the mission would be to discern if Europa's oceans harbour life"

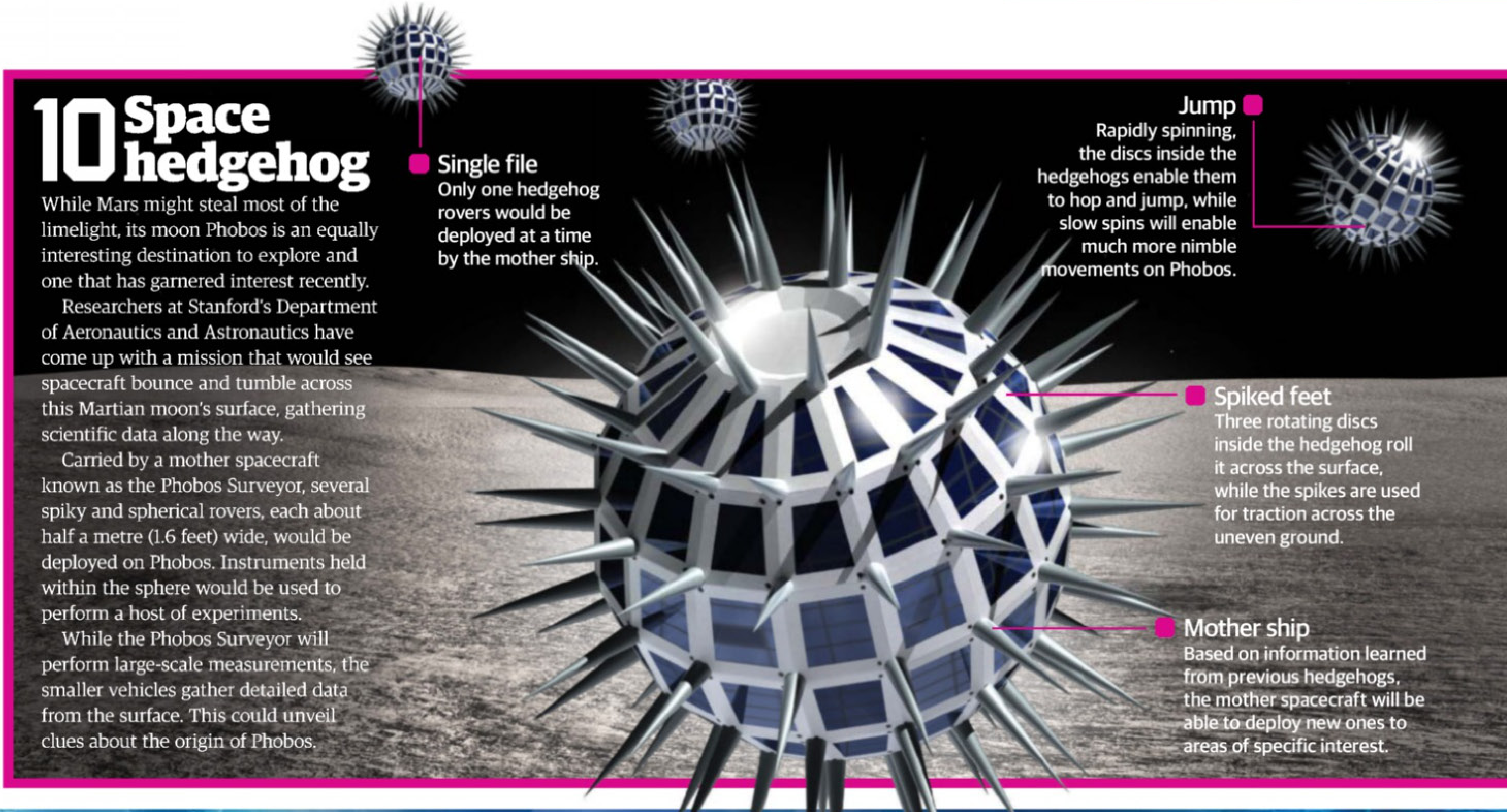
10 Space hedgehog

While Mars might steal most of the limelight, its moon Phobos is an equally interesting destination to explore and one that has garnered interest recently.

Researchers at Stanford's Department of Aeronautics and Astronautics have come up with a mission that would see spacecraft bounce and tumble across this Martian moon's surface, gathering scientific data along the way.

Carried by a mother spacecraft known as the Phobos Surveyor, several spiky and spherical rovers, each about half a metre (1.6 feet) wide, would be deployed on Phobos. Instruments held within the sphere would be used to perform a host of experiments.

While the Phobos Surveyor will perform large-scale measurements, the smaller vehicles gather detailed data from the surface. This could unveil clues about the origin of Phobos.

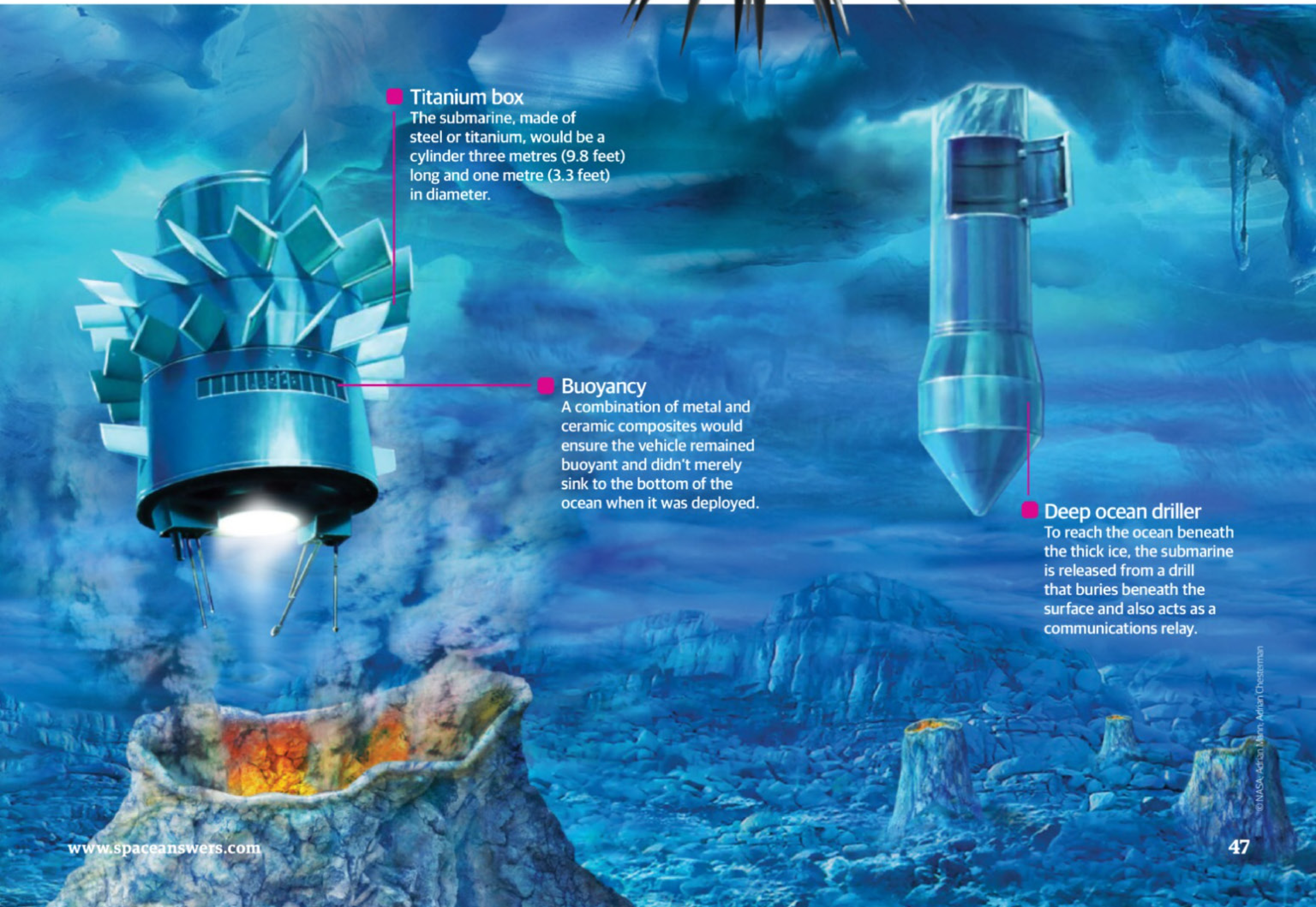


Single file
Only one hedgehog rovers would be deployed at a time by the mother ship.

Jump
Rapidly spinning, the discs inside the hedgehogs enable them to hop and jump, while slow spins will enable much more nimble movements on Phobos.

Spiked feet
Three rotating discs inside the hedgehog roll it across the surface, while the spikes are used for traction across the uneven ground.

Mother ship
Based on information learned from previous hedgehogs, the mother spacecraft will be able to deploy new ones to areas of specific interest.



Titanium box
The submarine, made of steel or titanium, would be a cylinder three metres (9.8 feet) long and one metre (3.3 feet) in diameter.

Buoyancy
A combination of metal and ceramic composites would ensure the vehicle remained buoyant and didn't merely sink to the bottom of the ocean when it was deployed.

Deep ocean driller
To reach the ocean beneath the thick ice, the submarine is released from a drill that buries beneath the surface and also acts as a communications relay.

© NASA; Adrian Mann; Adrian Chesterman

Fiery Orion nebula

The Orion nebula might look hot, but it's actually a cradle of young stars and freezing temperatures

It's a winter sky gem for many amateur astronomers and is the go-to target for telescopes, binoculars and even the naked eye. Located some 1,500 light years away in the constellation that it takes its name from, the Orion nebula (M42) is a place where stars are born. It's essentially a stellar nursery displayed in great volumes of gas and dust, clutching its young open star cluster – the Trapezium – to its heart.

This dramatic new image, captured by the European Southern Observatory-operated Atacama Pathfinder Experiment (APEX) in Chile, is a shot of this stunning diffuse nebula that's seldom seen. A fiery ribbon, glowing in a brilliant hue of oranges and reds, plays up the light coming from grains of interstellar dust.

You would be forgiven for thinking that this region, which can be seen extending from the luminous centre of M42, is a place of high temperatures. However this shot – revealed in a submillimetre-wavelength glow and showing light that's undetectable to the human eye – is a very cold place. In fact, the hottest places in the nebula sizzle in an icy blue.

Swathes of dust have been manipulated by strong stellar winds, blown out by the atmosphere of the nebula's stars to give the clouds their shape. These wavelengths have enabled astronomers to discover unusual objects lurking in this region of the universe, including 15 protostars – an early phase in star formation – that pop out as brilliant points of light. ■

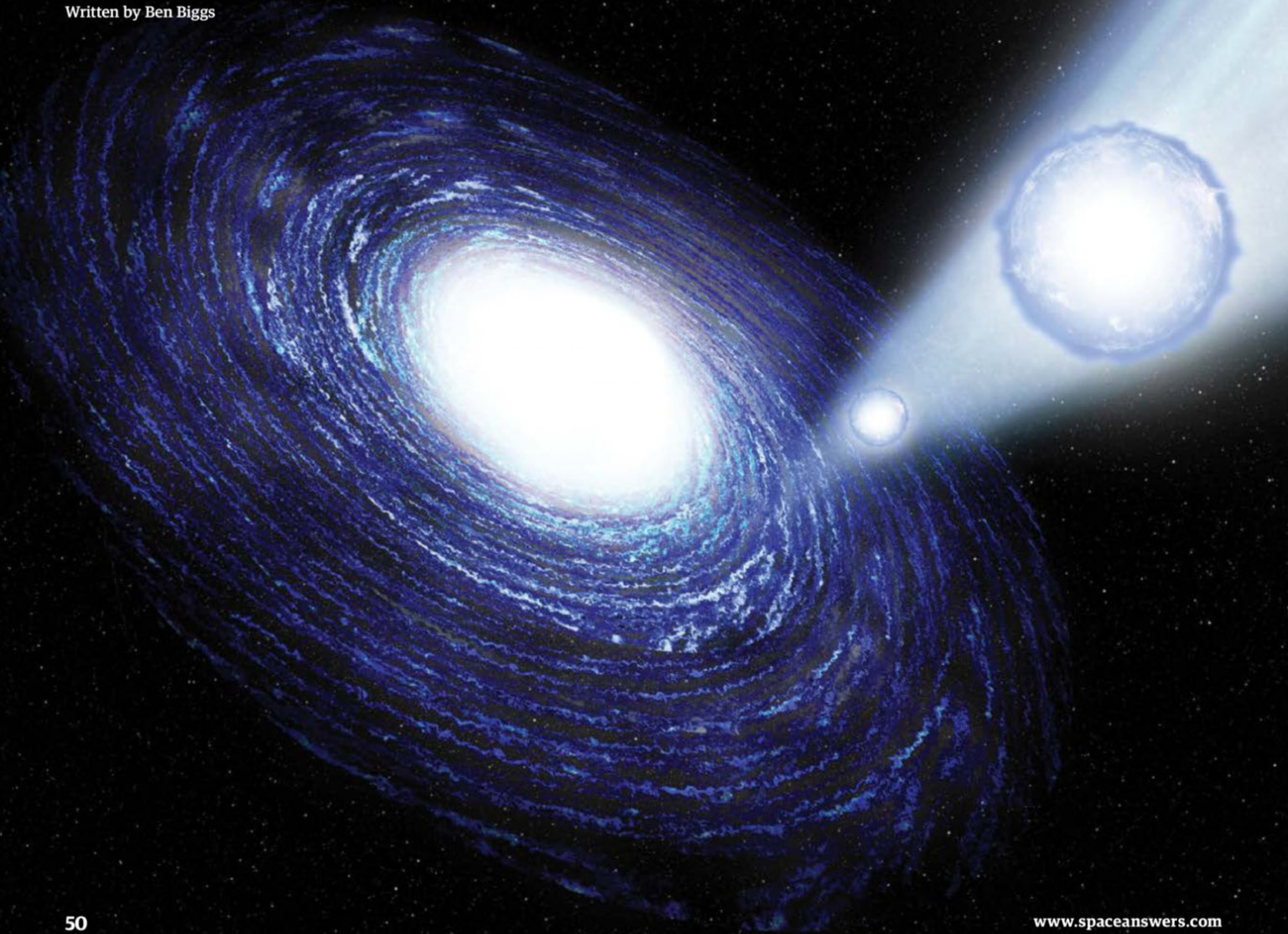
This shot of the Orion nebula, captured by the ESO's APEX telescope in the Chilean Andes, is one of the most detailed astronomical images ever produced

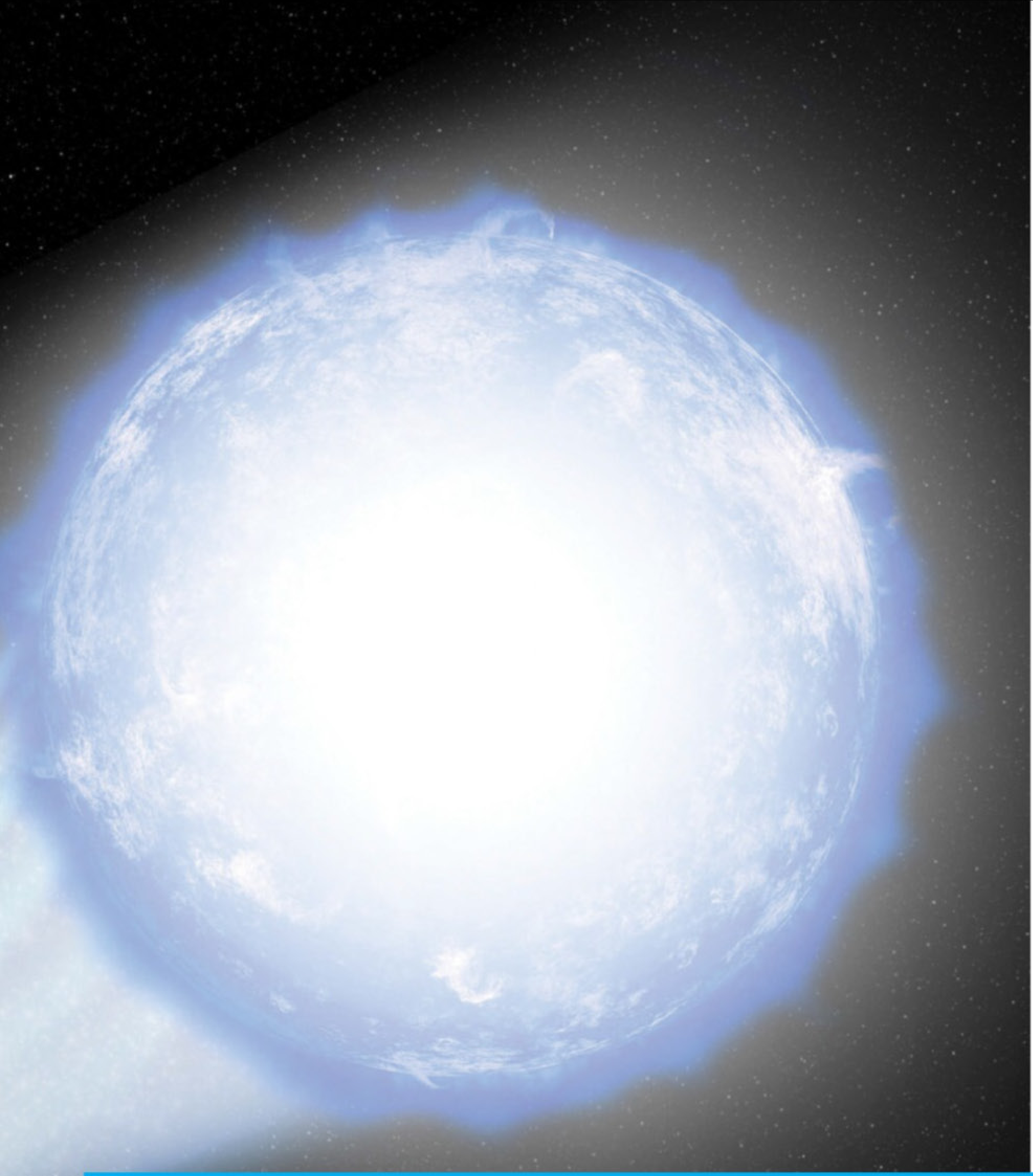
© ESO

Stellar outcasts

They move so fast that some can escape the mighty gravitational grasp of a galaxy, but how are these sprinting stars created?

Written by Ben Biggs





It's easy to think of the stars and their respective systems within the Milky Way as gravitationally bound to the galactic core, running a celestial circuit that takes thousands of years before starting all over again. But though the chronology of space might seem like an eternity to us, the universe is far too dynamic a place to enable this status quo to go undisrupted for long.

High-velocity stars travel faster relative to other bodies in the Milky Way and often ping around our galaxy for millennia before being flung out into interstellar space at fantastic speeds. Our Sun, travelling at around 83,700 kilometres (over 52,000 miles) per hour is hardly moving at a plodding pace through the galaxy. However, around 20 per cent of massive stellar objects in the Milky Way rip through the fabric of space at speeds upwards of 108,100 kilometres (67,000 miles) per hour, leaving others eating their stardust.

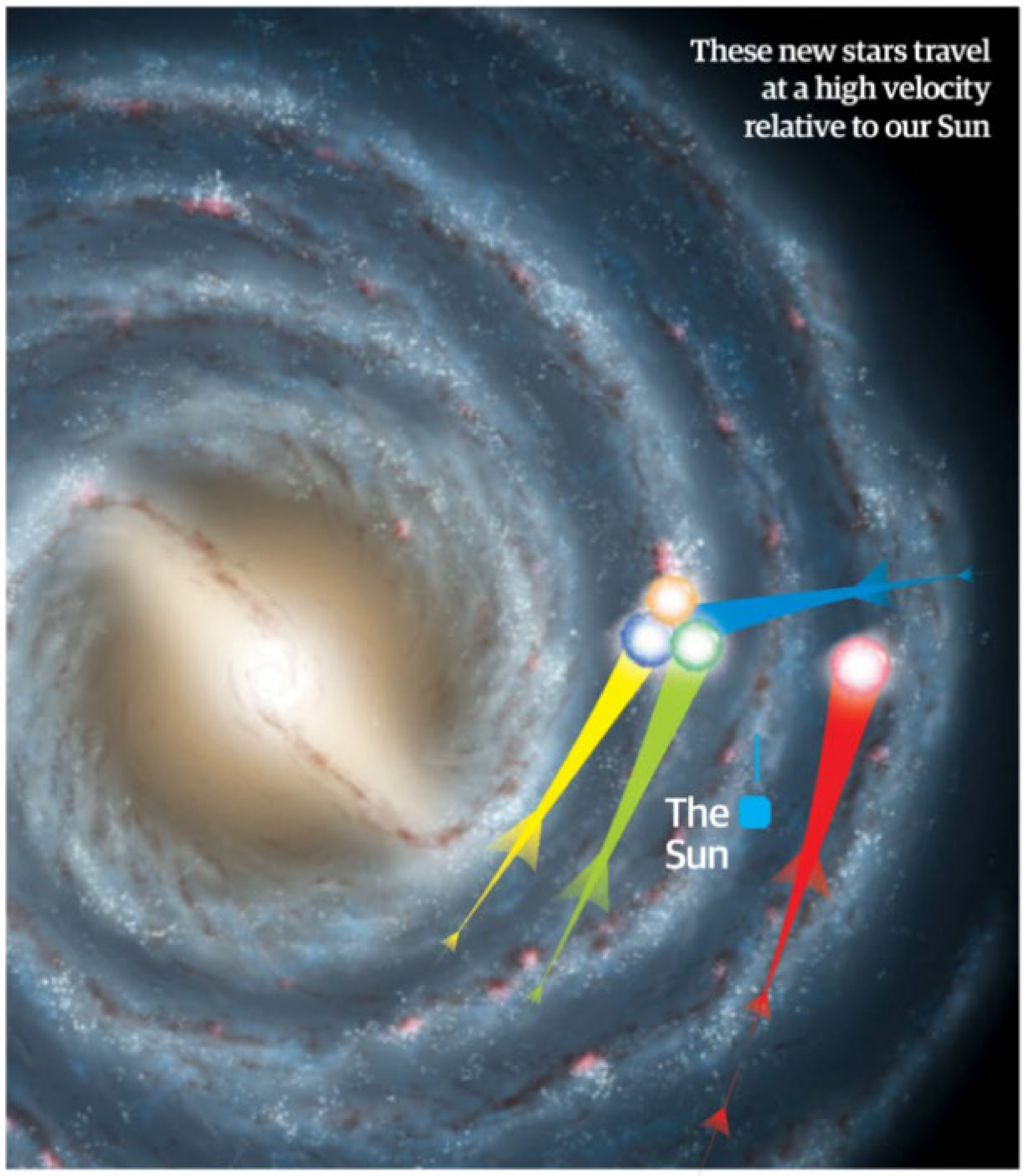
These unusually fast stars have been known about for over 50 years now, but it's only within the last 20 years that scientists have been able to fully explain how they move so fast, as well as how they gained the energy to put them out of sync with the rest of the galaxy in the first place.

High-velocity stars can be broadly split into three different categories: halo stars, runaway stars and hypervelocity stars. These objects can travel hundreds of kilometres per second faster than the average speed of stars located in the Sun's neighbourhood.

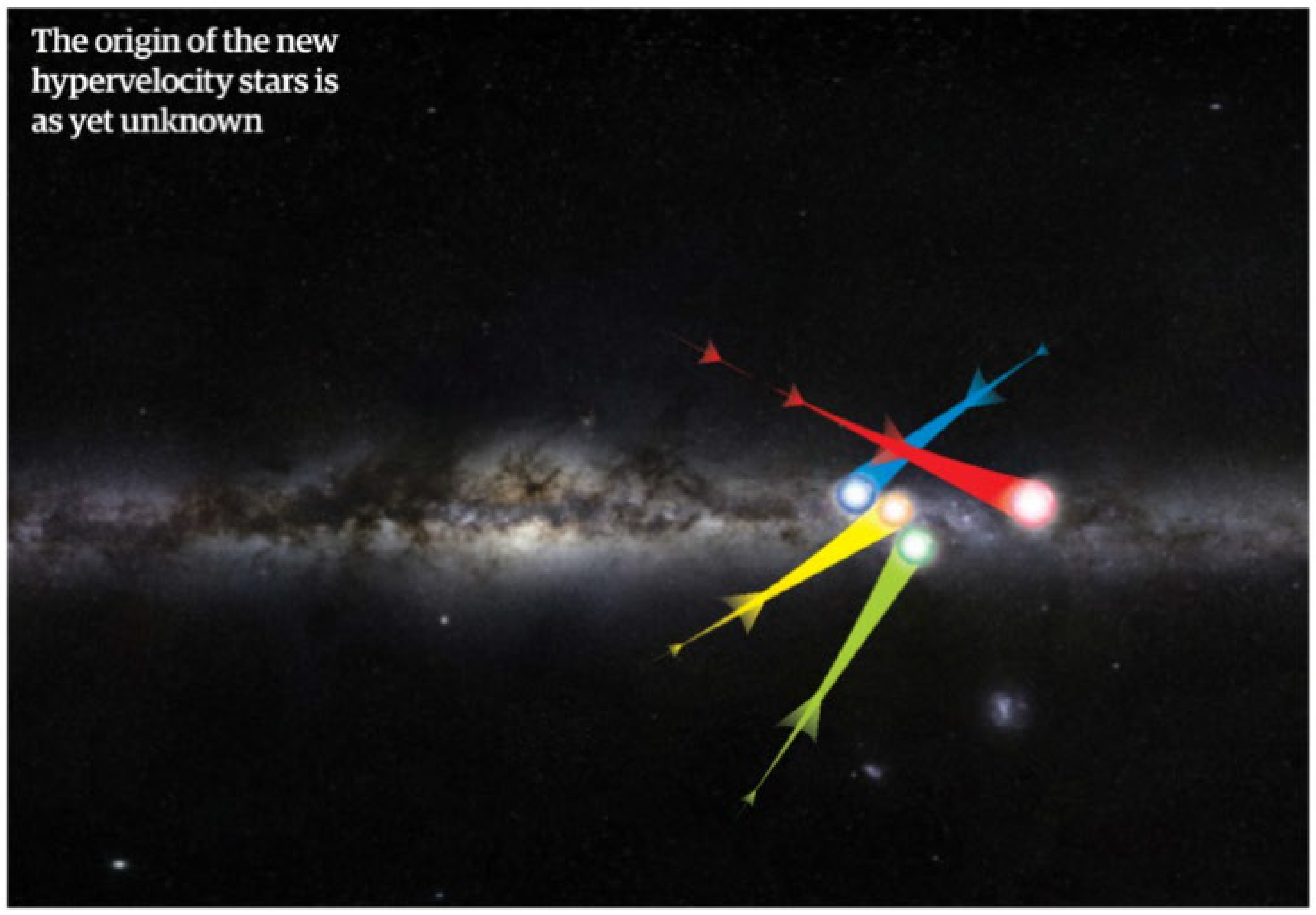
Halo stars are probably the least exciting, because they simply move differently to most other stellar objects in the neighbourhood of the Solar System. They are very old stars, with elliptical orbits that take them far beyond the main spherical body of the

Speedy imposters

Scientists recently discovered a new, Sun-sized class of hypervelocity star in the process of leaving the galaxy, whose origin wasn't the black hole core or the galactic halo. The view through the plane and top of the Milky Way in the images below show the trajectories and positions of three such stars relative to the Sun. Researchers are looking into where these new stars have come from and what has given them their enormous burst of speed.



These new stars travel at a high velocity relative to our Sun



The origin of the new hypervelocity stars is as yet unknown

Milky Way (the galactic halo), in a similar way Pluto has a very different orbit to the rocky inner planets. This means that they have high velocities relative to the Sun, but quite a normal average velocity relative to the centre of the galaxy. A good example is Kapteyn's star, a ten-billion-year-old red dwarf 13 light years from Earth and the closest halo star to us.

Runaway stars were once moving in a standard motion with a fairly typical velocity for stars in the Milky Way, until they were disrupted by some energetic force and hurled from the main body of the galaxy. They can be found moving at surprising speed at an unexpectedly huge distance from their points of origin and, unlike halo stars, are also the young and short-lived O and B types of stars. These super and hypergiants have enormous masses that burn brightly, using their fuel up quickly before bowing out in a supernova after just a few million years. Because of this, as well as the rarity of this type of star (one in 800 stars are Bs and one in three million are Os), an OB-type runaway tends to stand out to astronomers.

OB runaways can be formed in one of two ways. Some are born into tightly packed clusters that cannot support so many stars in such close proximity. Eventually they encounter a binary system – a pair of stars – that they gravitationally interact with in such a way that stars are hurled out of the cluster. Under computer-simulated conditions, a star cluster 5,000- to 10,000-times more massive than the Sun tends to display this behaviour and dense clusters may gain mass and shrink over time by shooting stars out of it in this way.

While gravitational interaction is responsible for some OB runaways, the more common and exciting origins for stellar outcasts of this type are supernovas. Massive binary star systems don't stay partners for long and ultimately the more massive of the two stars will explode violently, giving the other half of the pair a huge acceleration blast, or kick, through space.

You'd be forgiven for thinking that these enormously energetic blasts act as waves, carrying the star off into the cosmos. However, the sudden release of the gravitational forces binding the two stars is what gives the OB runaway its boost. It's the same physical mechanic that governs the hammer thrower at an athletics event: one moment you're spinning around with the hammer and suddenly, you let go, enabling it to fly off down the field. Massive binary stars orbit one another at extremely high speeds and when one is thrown out in a supernova, the other flies off in a straight line while preserving its high orbital velocity.

Curiously, the neutron star, or black hole remnant, of the OB runaway's former partner will remain gravitationally bound in orbit around the runaway as it takes its new trajectory across the galaxy.

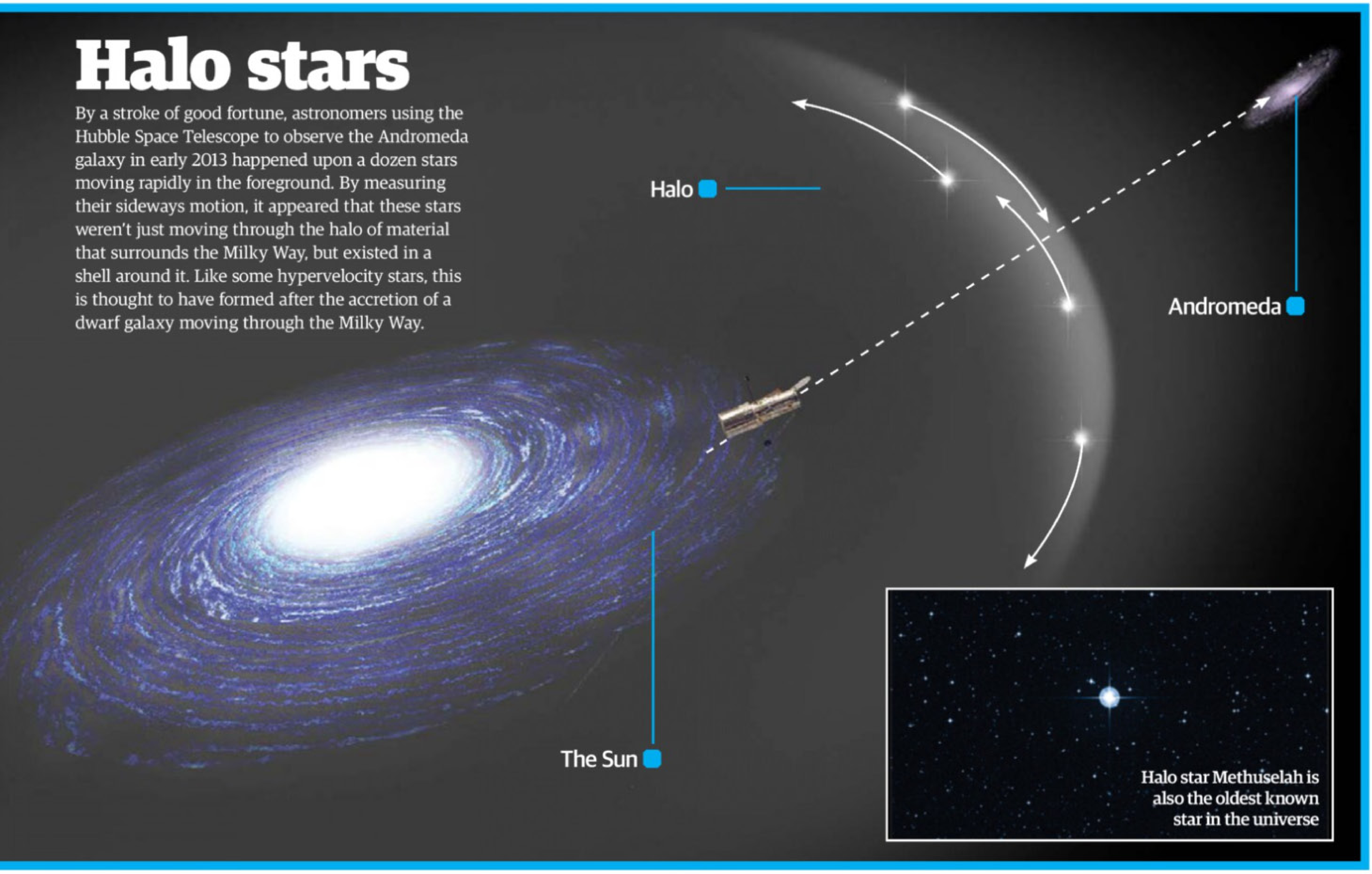
A telling example of an OB runaway, discovered with the remnants of its former stellar partner in tow, was Vela X-1. This blue supergiant (designated the codename HD 77581) can be found in the constellation Vela along with its binary neutron star, which pulses powerful X-rays in regular 283-second intervals and is the brightest source of this type of radiation in the constellation.

The key indicator that this pair is an OB runaway and not a regular binary system is the remarkably clean lines of its bow shock. This is a feature much like the wake created by the prow of a ship, where the stellar wind blowing off HD 77581 meets the interstellar medium. It shows that the runaway is moving north at a fantastic velocity of around 90

> "Runaway stars were once moving in a standard motion with a fairly typical velocity for a star in the Milky Way"

Halo stars

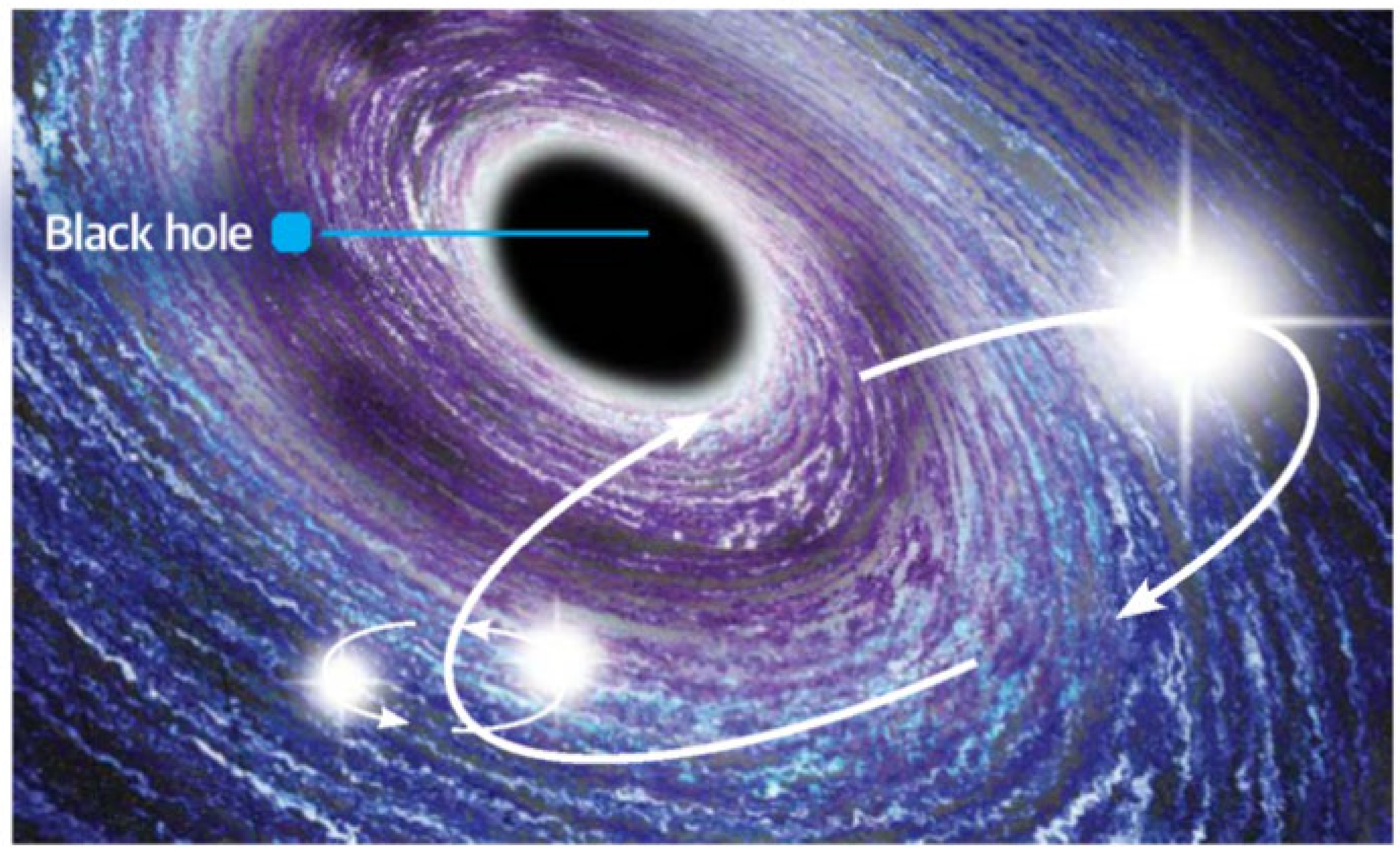
By a stroke of good fortune, astronomers using the Hubble Space Telescope to observe the Andromeda galaxy in early 2013 happened upon a dozen stars moving rapidly in the foreground. By measuring their sideways motion, it appeared that these stars weren't just moving through the halo of material that surrounds the Milky Way, but existed in a shell around it. Like some hypervelocity stars, this is thought to have formed after the accretion of a dwarf galaxy moving through the Milky Way.



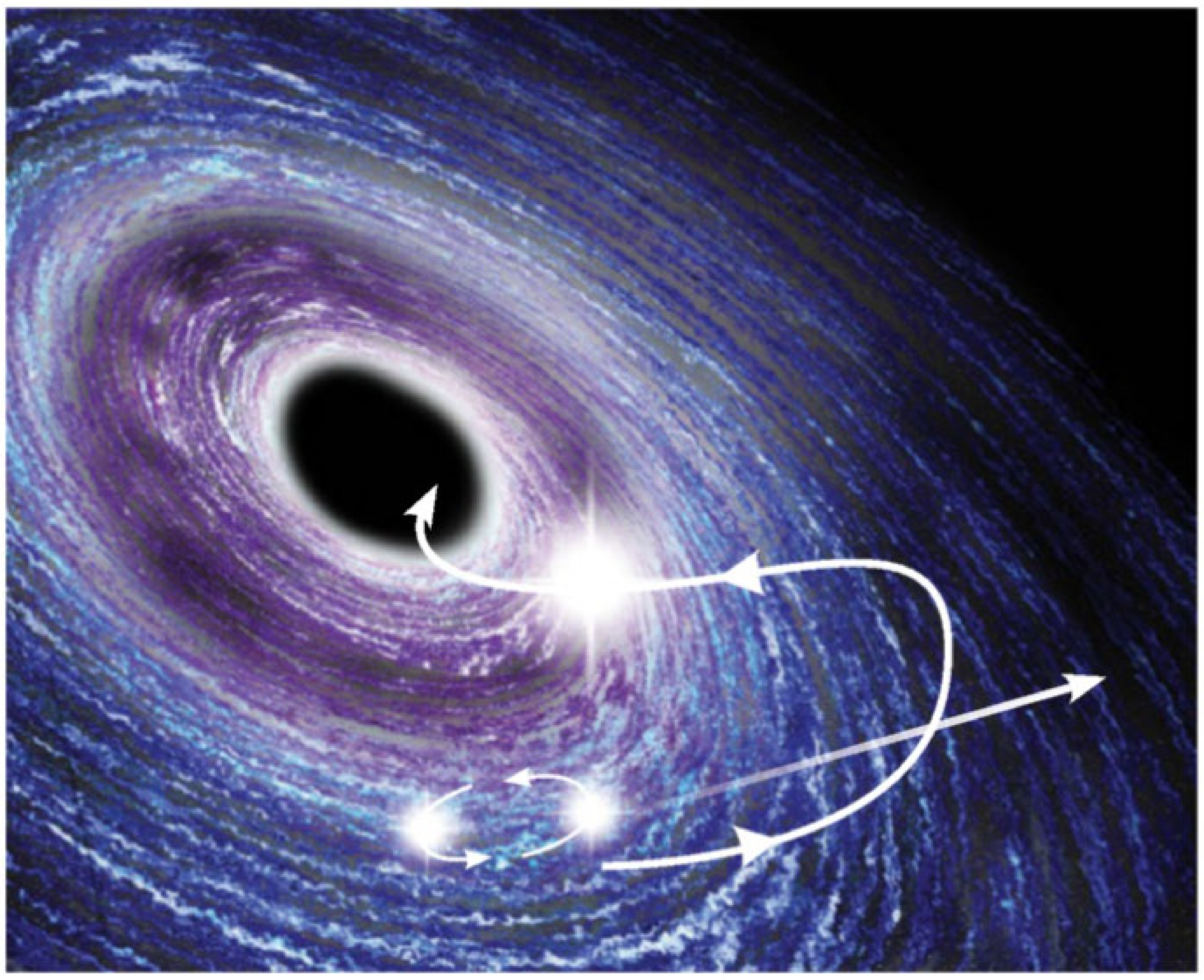
Halo star Methuselah is also the oldest known star in the universe

Blue stragglers

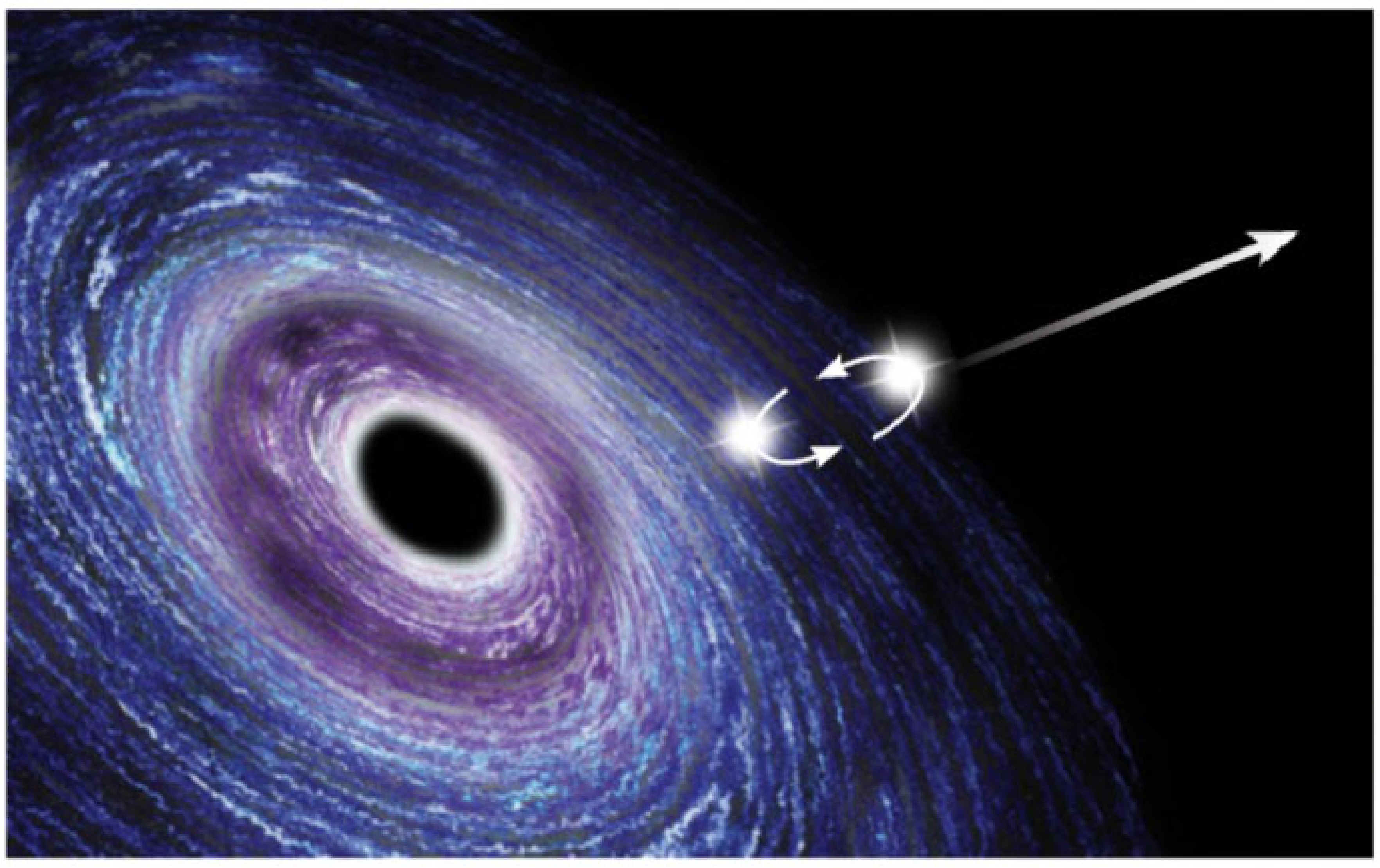
How a massive blue star can be ejected from the Milky Way



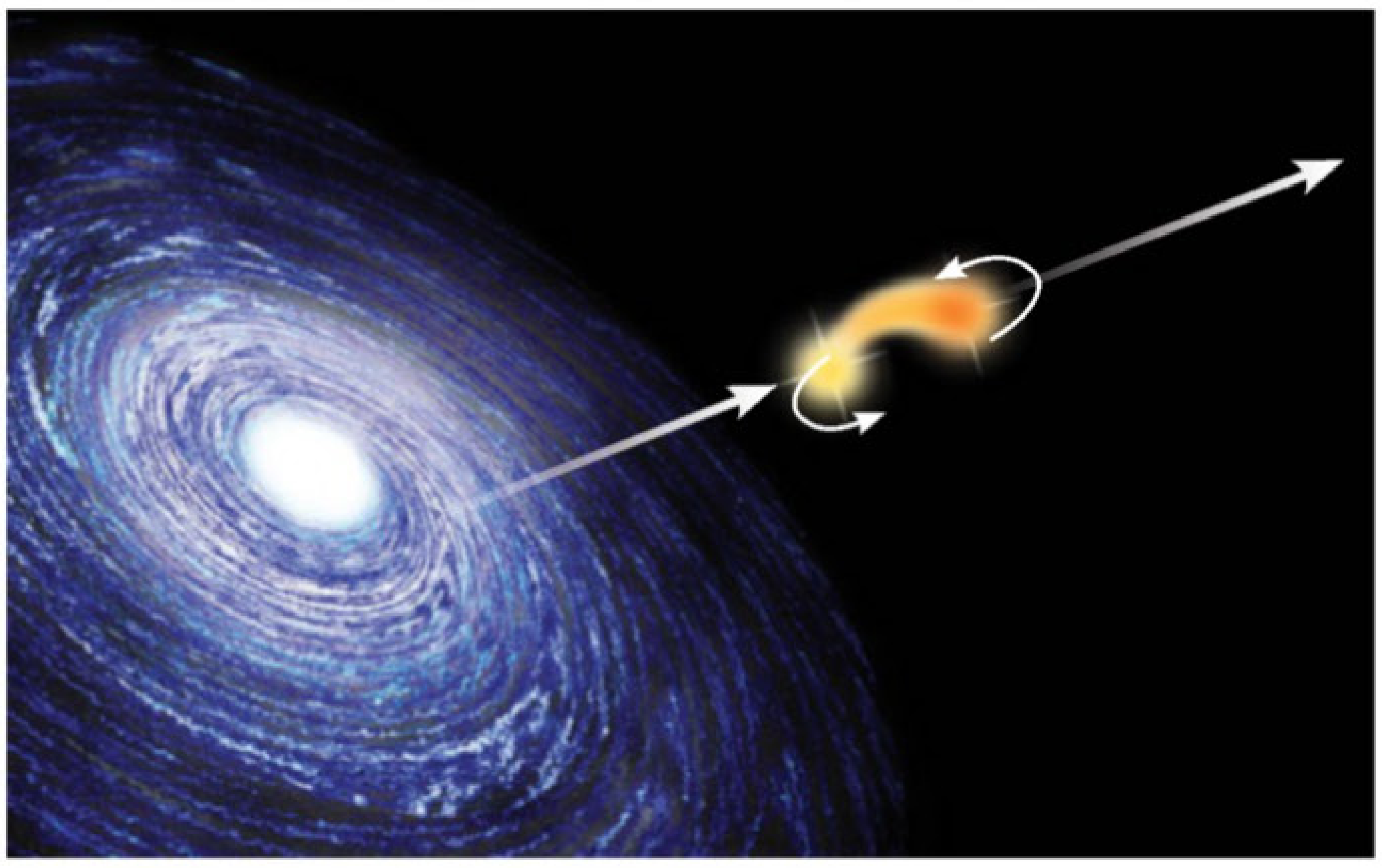
1. Galactic core approach
The triple star system begins to approach Sagittarius A*, the supermassive black hole at the core of the Milky Way.



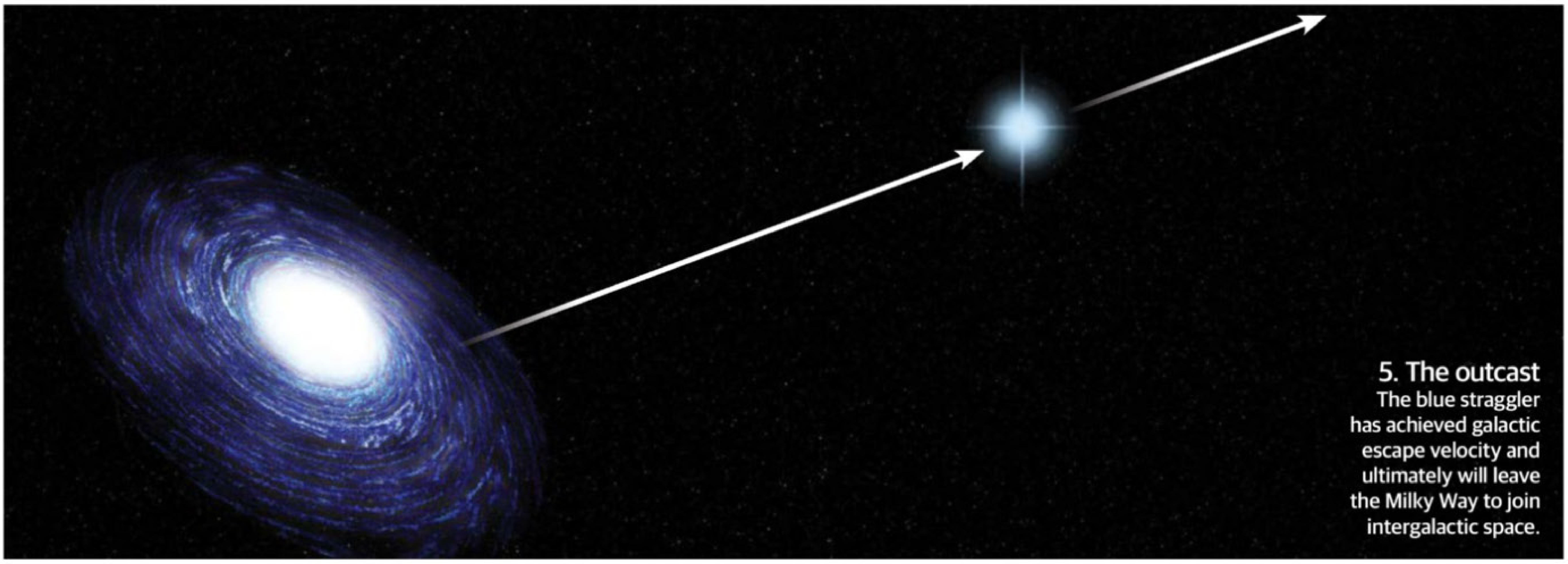
2. Torn apart
As the system falls under the influence of the black hole's enormous gravity, one of the three stars is pulled away into orbit around or sucked into the black hole itself.



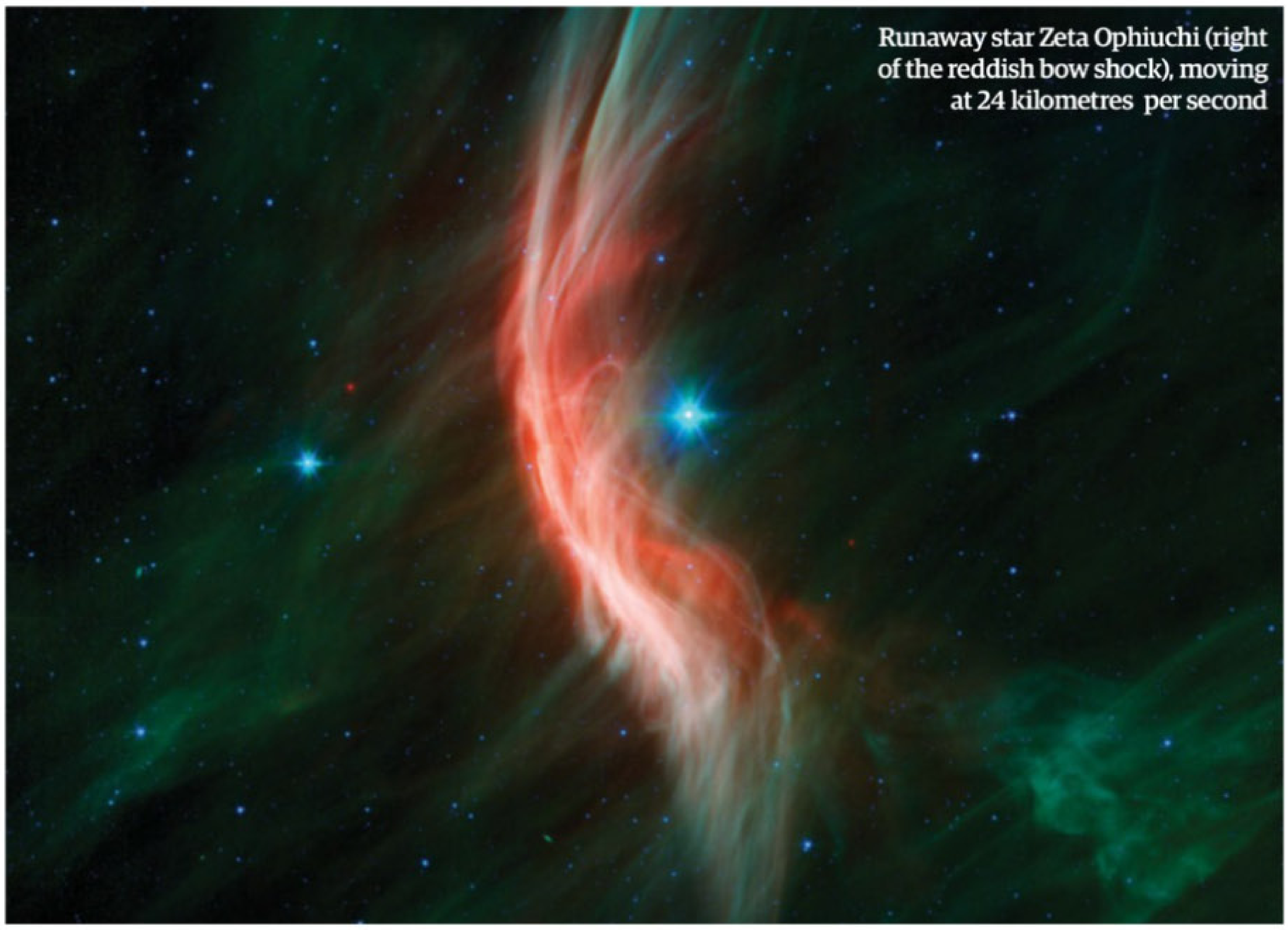
3. The kick
As one star is torn away, the remaining binary recoils with an enormous gravitational 'kick' that sees it fly off at its orbital velocity in a straight line.



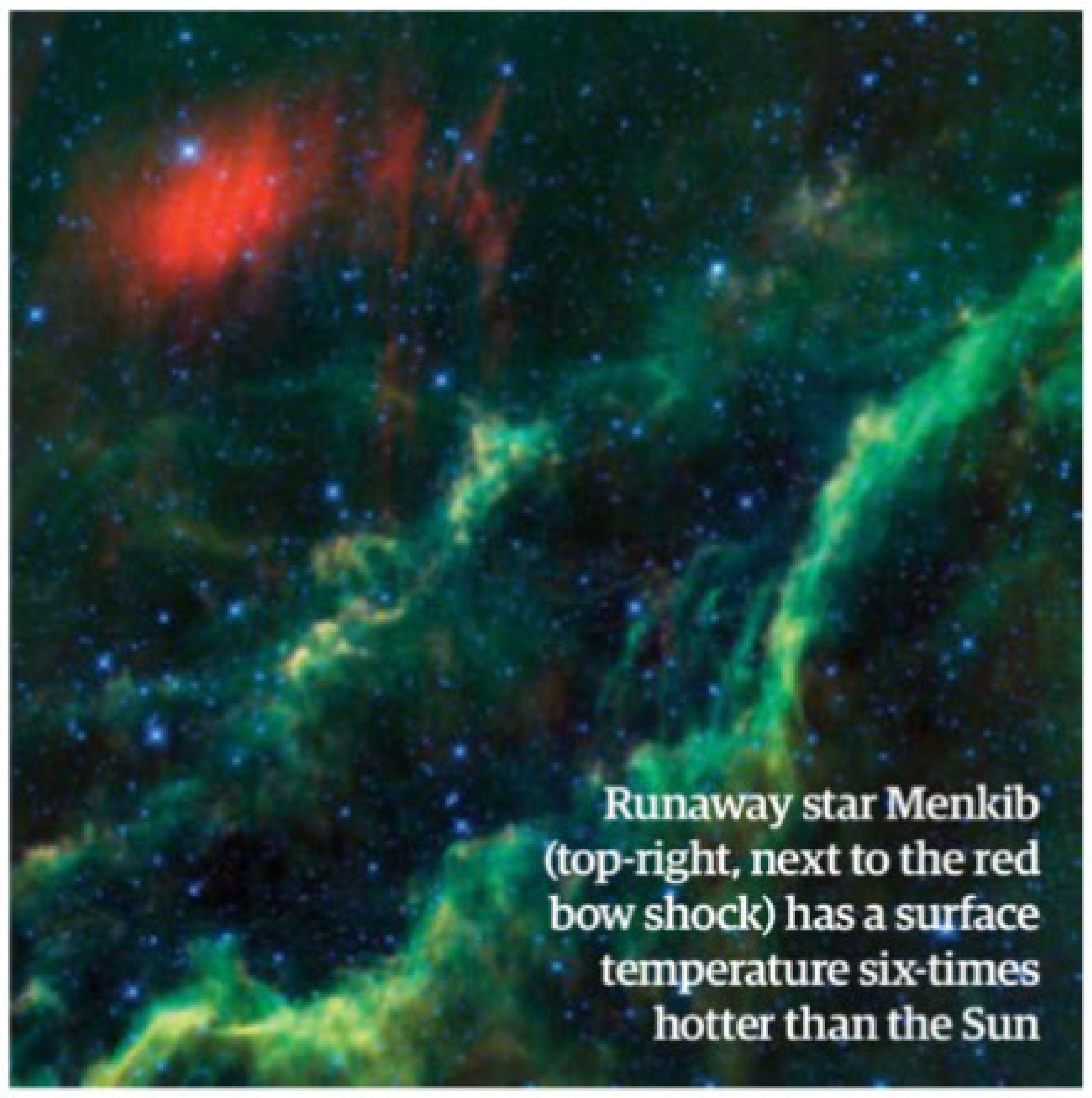
4. Merger
As they travel further though the galaxy, and away from the black-hole core, the stars begin to merge into one giant blue star.



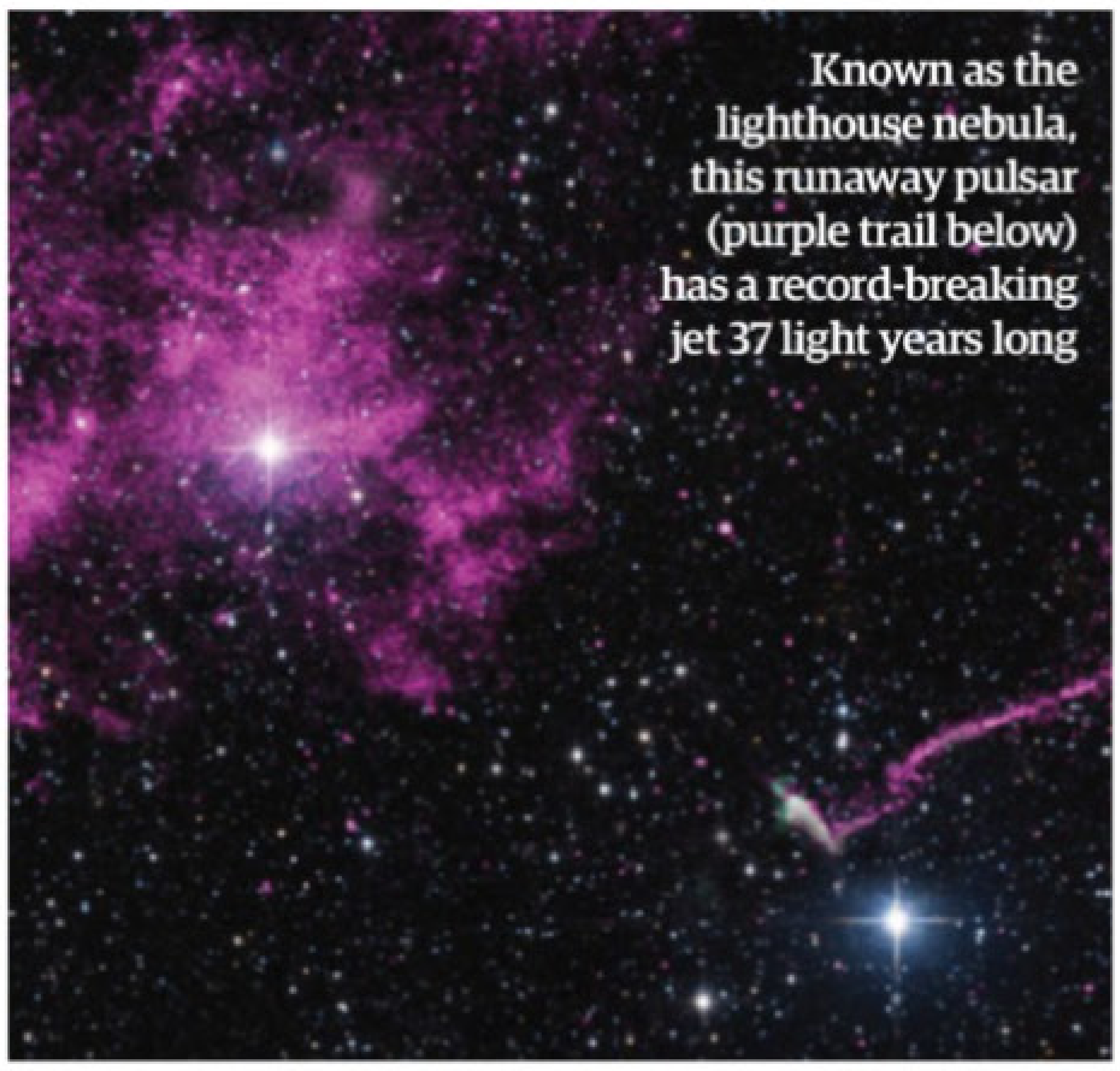
5. The outcast
The blue straggler has achieved galactic escape velocity and ultimately will leave the Milky Way to join intergalactic space.



Runaway star Zeta Ophiuchi (right of the reddish bow shock), moving at 24 kilometres per second



Runaway star Menkib (top-right, next to the red bow shock) has a surface temperature six-times hotter than the Sun



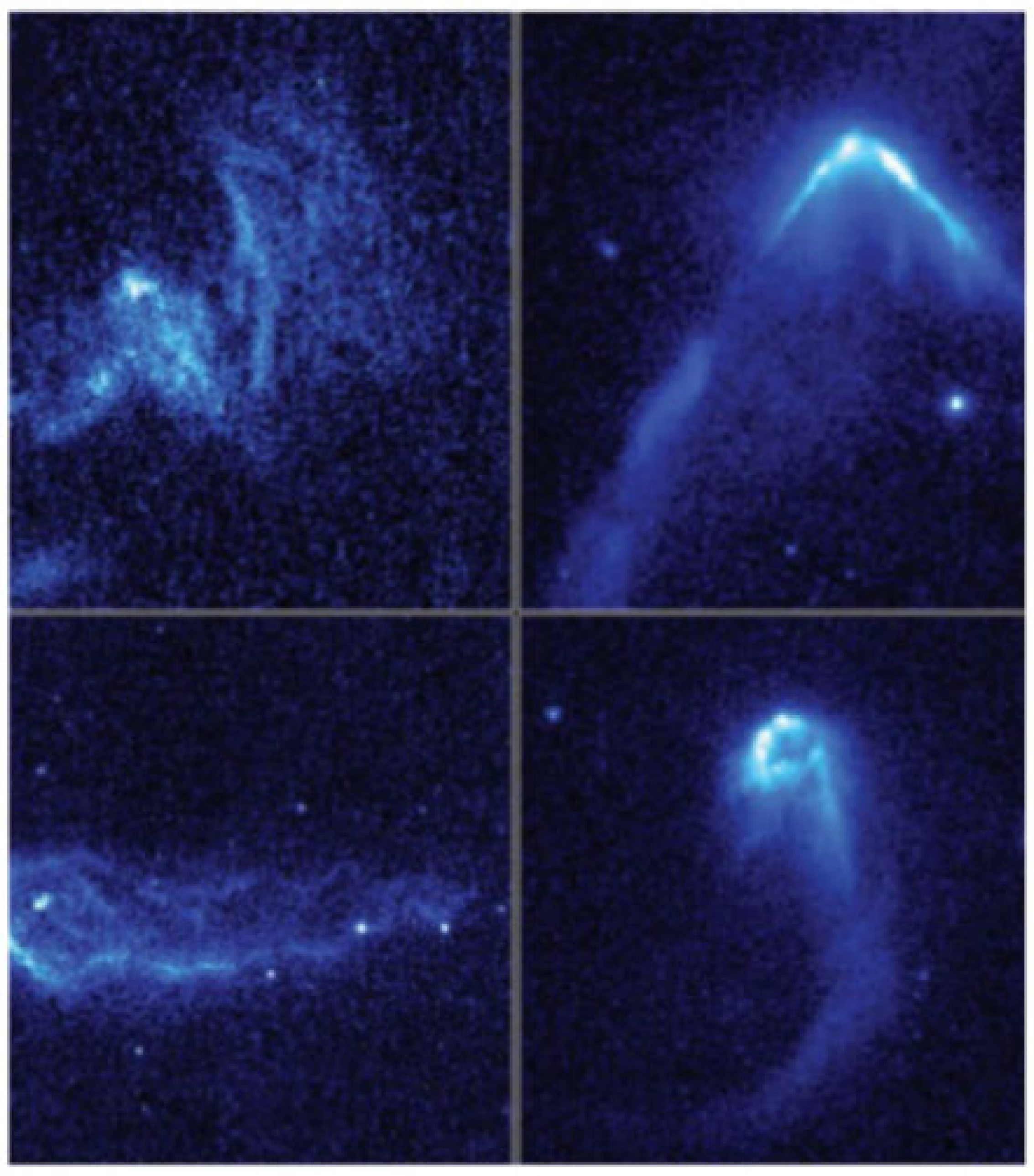
Known as the lighthouse nebula, this runaway pulsar (purple trail below) has a record-breaking jet 37 light years long

kilometres (56 miles) a second, which puts it at precisely the expected time and place of Vela X-1's progenitor supernova, 2.5 million years ago.

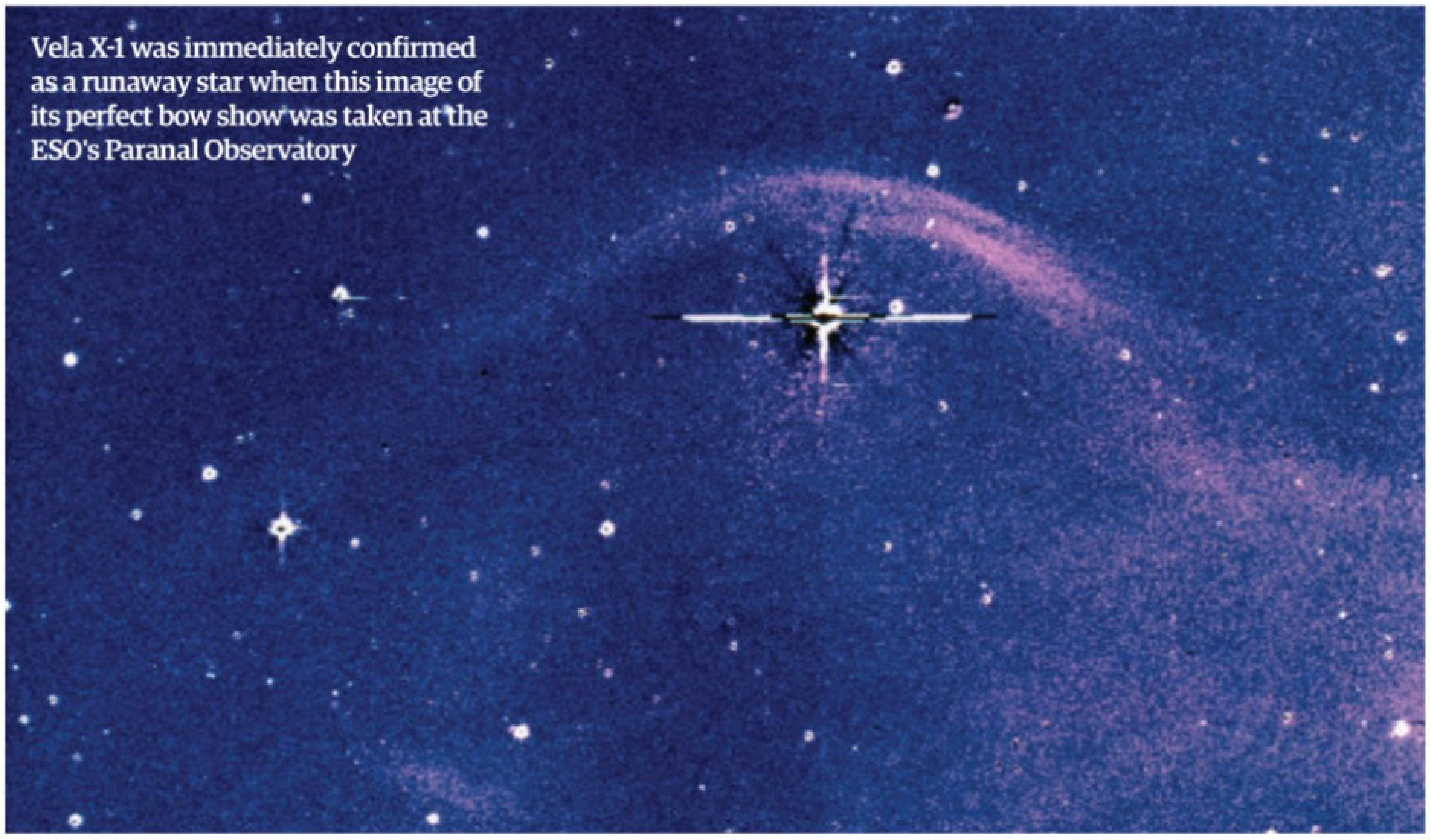
The final class of high-velocity star is a new discovery for science. Hypervelocity stars move through our galaxy at a break-neck pace that far exceeds that of OB runaways, even. They move fast enough to achieve escape velocity from the Milky Way, in excess of 1.6 million kilometres (1 million miles) an hour relative to the galaxy's motion, meaning they're able to speed away into intergalactic space and can even find themselves captured by other galaxies.

Even the energy of being released from a binary partner in a massive supernova can't account for the speed that some hypervelocity stars travel at. It's extremely difficult to kick a star out of a galaxy once it's been captured, so these stars must get a big boost from some other source. Scientists can trace the point of origin of most large, blue hypervelocity stars back to a binary pair at the centre of the galaxy. Here, the supermassive black hole Sagittarius A* flexes the gravitational muscle of its four million solar masses and pulls the pair in. As they're drawn towards the event horizon, one is pulled into orbit around the black hole (and possibly into it), while the other gets a huge kick in the opposite direction, ripping the pair apart and propelling the newly born hypervelocity star away from the core at an incredible pace.

A total of 18 hypervelocity stars are known about altogether, although around 1,000 are thought to exist in the Milky Way, which is just one-millionth of one per cent of the 100 billion stars in our galaxy. Several groups of astronomers have even suggested that some of these high-velocity stars are the result of an ancient merger with a dwarf galaxy that was orbiting the Milky Way. As it passed through our galactic core, the supermassive black hole pulled one of the triple-star systems away, tearing a star off and flinging the remaining pair into space. Unlike other high-velocity stars, these blue stragglers began their exit from the galaxy as a pair, but have merged into one, increasing their mass and extending their life before a supernova. ●



Four runaway stars moving through dense interstellar gas in an image taken by the Hubble Space Telescope



Vela X-1 was immediately confirmed as a runaway star when this image of its perfect bow show was taken at the ESO's Paranal Observatory

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The Valkyrie super robot

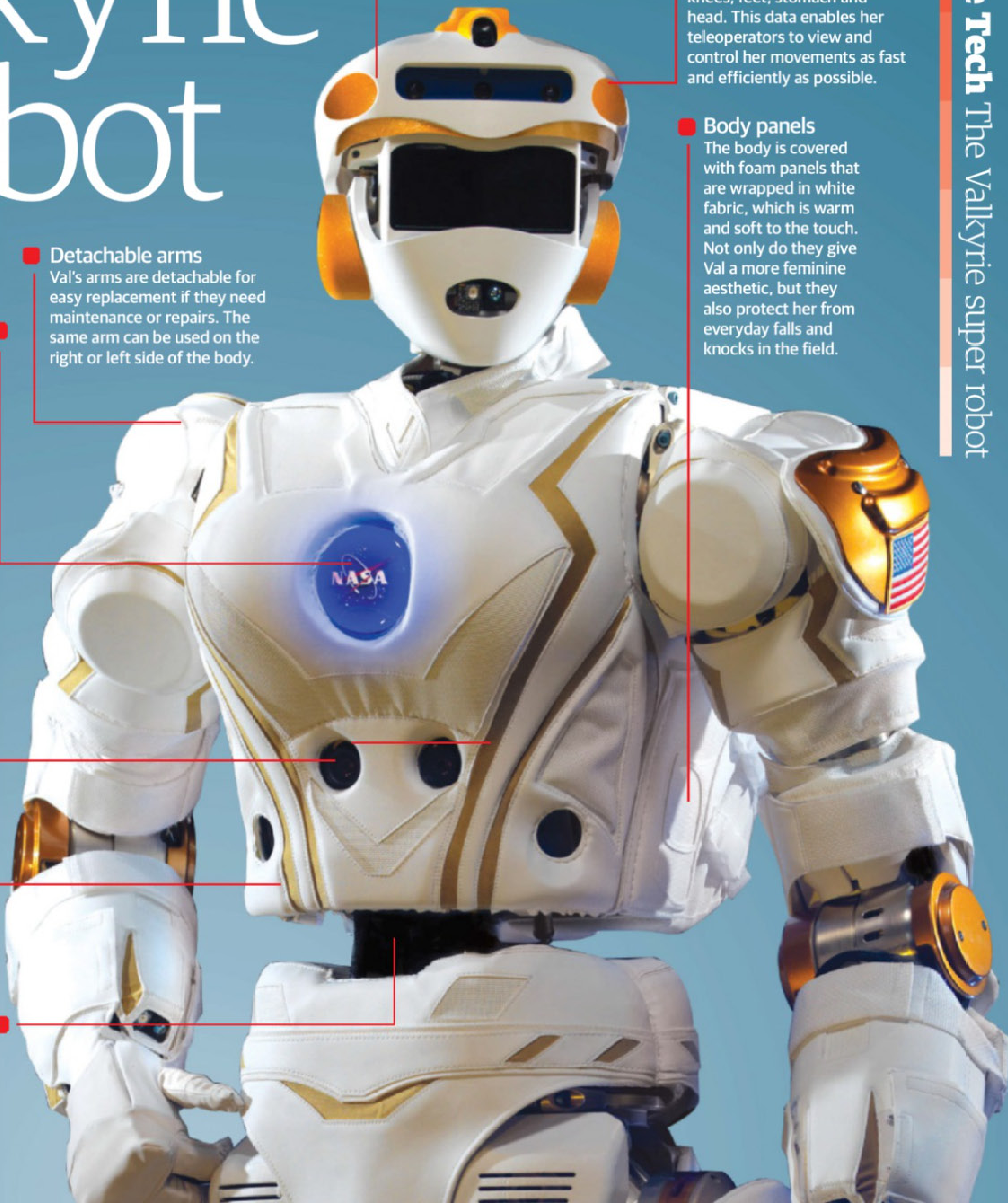
How NASA's answer to Iron Man will explore the Red Planet

Valkyrie is a humanoid robot that's an impressive 1.9 metres (6.2 feet) tall and weighs 130 kilograms (286 pounds). Nicknamed Val, she was created at NASA's Johnson Space Center, Houston, Texas, by engineers who were involved in the development of Robonaut. Unlike Robonaut, which has a humanoid torso and is currently being operated and tested on the International Space Station, Val has a full humanoid body and is capable of walking.

The ability to walk means that Val can work beyond the confines of a spaceship and could be deployed on the surface of the Moon, asteroids or Mars. To meet the challenge of walking independently on uneven terrain (like that on planetary bodies), as well as for her to pick up and manipulate objects, Val is supplied with a multitude of sensors and cameras. These are part of a control interface that gives her some autonomy, combined with overall remote control of her movement by human controllers.

While Robonaut was designed to work in a weightless environment, Val is built to cope with operating on Earth and to duplicate human-like activities. Val can therefore swivel and tilt her head, rotate her waist and has three fingers and a thumb to manipulate objects. This makes her far more versatile as an explorer or worker. She has also been given a softer appearance and even her surface is covered with a white fabric that is warm to the touch. Making her look and feel more human, rather than built like a walking tin can, is intended to make her more acceptable to astronauts who will be working with her.

In the long term, upgraded humanoid robots like Val would be ideal for helping us explore



Brains
For use on Mars, Val would require a more-powerful computer brain to enable her to operate autonomously when she's out of touch with her human teleoperators.

Cameras and sensors
Cameras along with LIDAR (laser) and sonar sensors are located on Val's forearms, knees, feet, stomach and head. This data enables her teleoperators to view and control her movements as fast and efficiently as possible.

Body panels
The body is covered with foam panels that are wrapped in white fabric, which is warm and soft to the touch. Not only do they give Val a more feminine aesthetic, but they also protect her from everyday falls and knocks in the field.

Detachable arms
Val's arms are detachable for easy replacement if they need maintenance or repairs. The same arm can be used on the right or left side of the body.

Chest
The chest is padded for protection and contains linear actuators to rotate her waist. The chest light helps highlight that she's a superhero robot.

Protection
Val's electronic components would need extra protection against radiation and the extremes of hot and cold on the Martian surface.

Battery power unit
A 2kWh battery mounted on the back of Val supplies enough power for one hour of operation. Luckily it can be replaced in just a few minutes.

Power
Val's battery life would have to be improved and supplemented with solar or other power sources on the Red Planet.

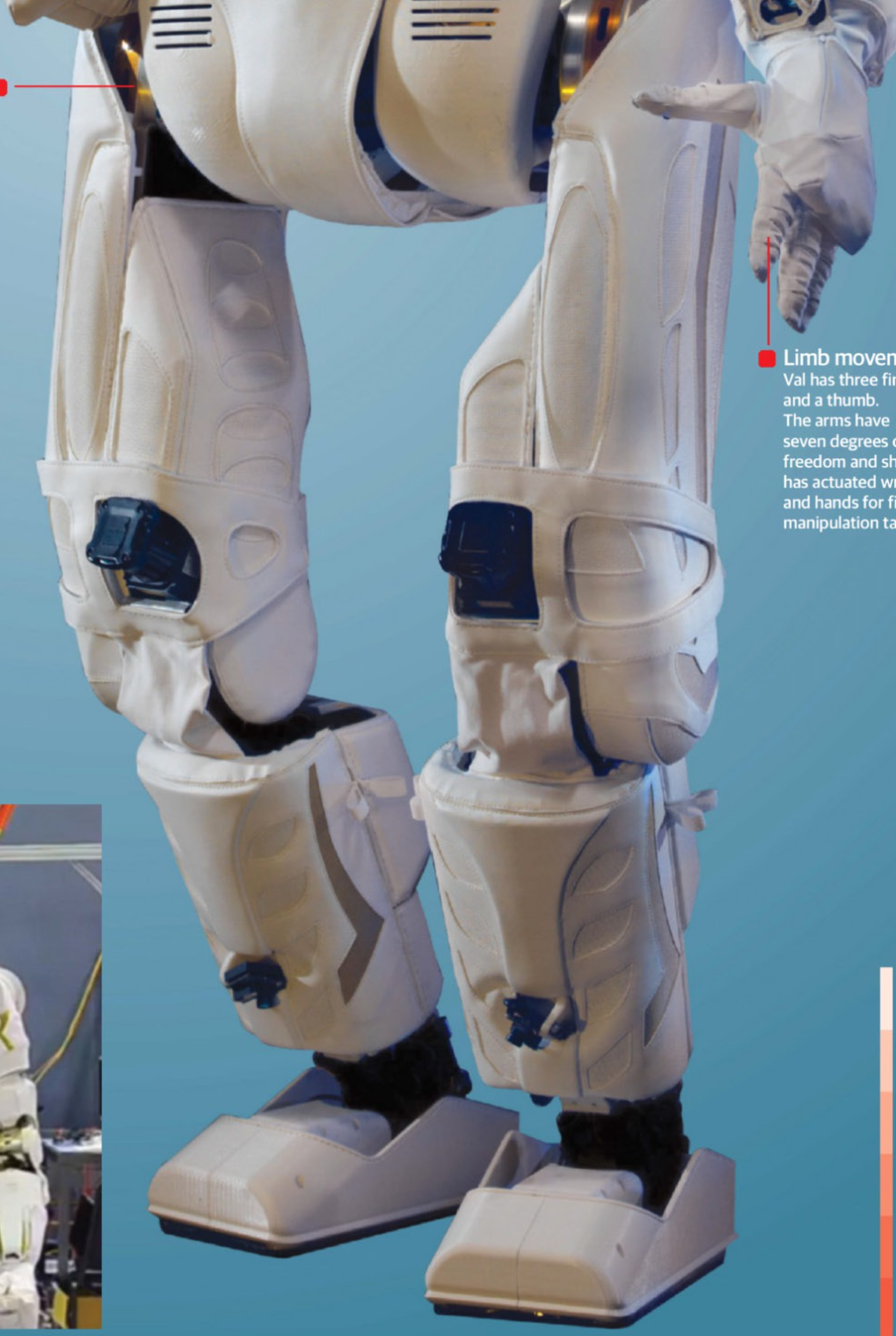
Mars, where the conditions are extremely harsh for human existence. This would mean adding essential protective shielding for her electronics against radiation and the Martian climate, as well as providing far more powerful computer abilities to enable her to work for longer without the input of remote human operators.

Longer battery power is another requirement for an outer-space version of Val. The present model uses a battery pack that only lasts for one hour before it needs replacing. One option is to give her the ability to change her own battery pack when required, or if she doesn't need to travel far, she could even be tethered to a power/data cable.

The next generations of Valkyries could be sent to near-Earth asteroids to assist with mining for rare minerals, or even act as advance parties on Mars, building structures for astronauts and preparing for their arrival. The robots would then work with the human astronauts to establish these colonies and help explore the planet in greater detail.

> "The next generations of Valkyries could be sent to near-Earth asteroids"

©NASA; YouTube



Legs

Her legs have six degrees of freedom of movement. To help her walk unaided, she has six-axis force-torque sensors fitted in her feet.

Limb movement

Val has three fingers and a thumb. The arms have seven degrees of freedom and she has actuated wrists and hands for fine manipulation tasks.

All About... THE VIRGO SUPERCLUSTER

One of the largest known structures in the universe, this supercluster is home to our own galaxy – and thousands of others

Written by Shanna Freeman

While it can be difficult to visualise just how our planet fits in with the rest of the universe, it may be helpful to realise that it's just one element in a much larger picture. Much like a set of Russian matryoshka (nesting) dolls, there are numerous layers.

Our Milky Way – containing the Solar System, along with billions of other stars – is part of a group of galaxies called the Local group, located inside a larger group of galaxy groups and clusters called the Virgo supercluster (VS). A supercluster is essentially a massive group of galaxies, which in turn may be classified into groups and clusters.

This means our own galaxy is just one of thousands in the VS, which has a volume 100 billion times that of the Milky Way. Superclusters don't exist as entirely separate, uniform structures in the universe, though; instead they're grouped in what astronomers term walls, sheets and filaments. Between these there are wide expanses of mostly empty space. All together, this structure is often called the cosmic web.

The VS is named after the Virgo cluster located at its heart (located in the Virgo constellation) and has an estimated diameter of 110 million light years. Also known as the Local supercluster (LS), it's one of millions of other superclusters in the known universe. Although these are massively large structures, research shows that the VS is small when compared with other superclusters.

The VS comprises of two main structures: a disk and a spherical halo. The disk is a flattened ellipsoid, less than one megaparsec (3,261,633 light years) wide and containing nearly 70 per cent of the galaxies, while the halo contains the rest. The galaxies are grouped into substructures called clouds. In the disk nearly all of the galaxies are in 11 main clouds, while in the halo they're concentrated in about seven clouds. The Virgo cluster is considered to be the richest galaxy cluster within the VS and the Local group is located in a filament near the outer edge of the disk.

So, how does the VS stack up against other superclusters? Its closest rival is the Hydra-Centaurus supercluster, at 100 million light years long. This is sometimes separated into two distinct superclusters and is very similar to the VS in that it has one rich galaxy cluster and likely has the same number of galaxies. The next closest supercluster, Perseus-Pisces, is one of the largest known superclusters in the universe. This is a dense wall of galaxies that spans about 300 million light years and borders the Taurus Void, a large circular empty space surrounded by walls of galaxies. By contrast, the Pavo-Indus supercluster is considered rather sparse and small, with no rich galaxies at all.

The VS, like all galaxy clusters, is bound together by gravitational attraction. There's also a whole lot of movement going on – and much of it isn't that well understood. We do know that the entire VS rotates around its centre of mass and it's also moving through space. The galaxies rotate too, as well as interact with one another. The Local group is estimated to be rotating around the centre of the VS at 400 kilometres (250 miles) per second, for instance. Two of the galaxies in the Local group, the Milky Way and Andromeda, are spiral arm galaxies that are moving towards each other at a speed of 110 kilometres (68 miles) per second. They are estimated to collide and form one huge elliptical galaxy in about four billion years.

Then there's the fact that the universe itself is expanding, so gravitational attraction is pulling all of the galaxies, galaxy clusters and superclusters towards one another. The accepted model is that this is happening equally in all directions. However, there's another mysterious force pulling on the VS (along with other local superclusters), towards the Norma cluster, moving at over 600 kilometres (373 miles) per hour.

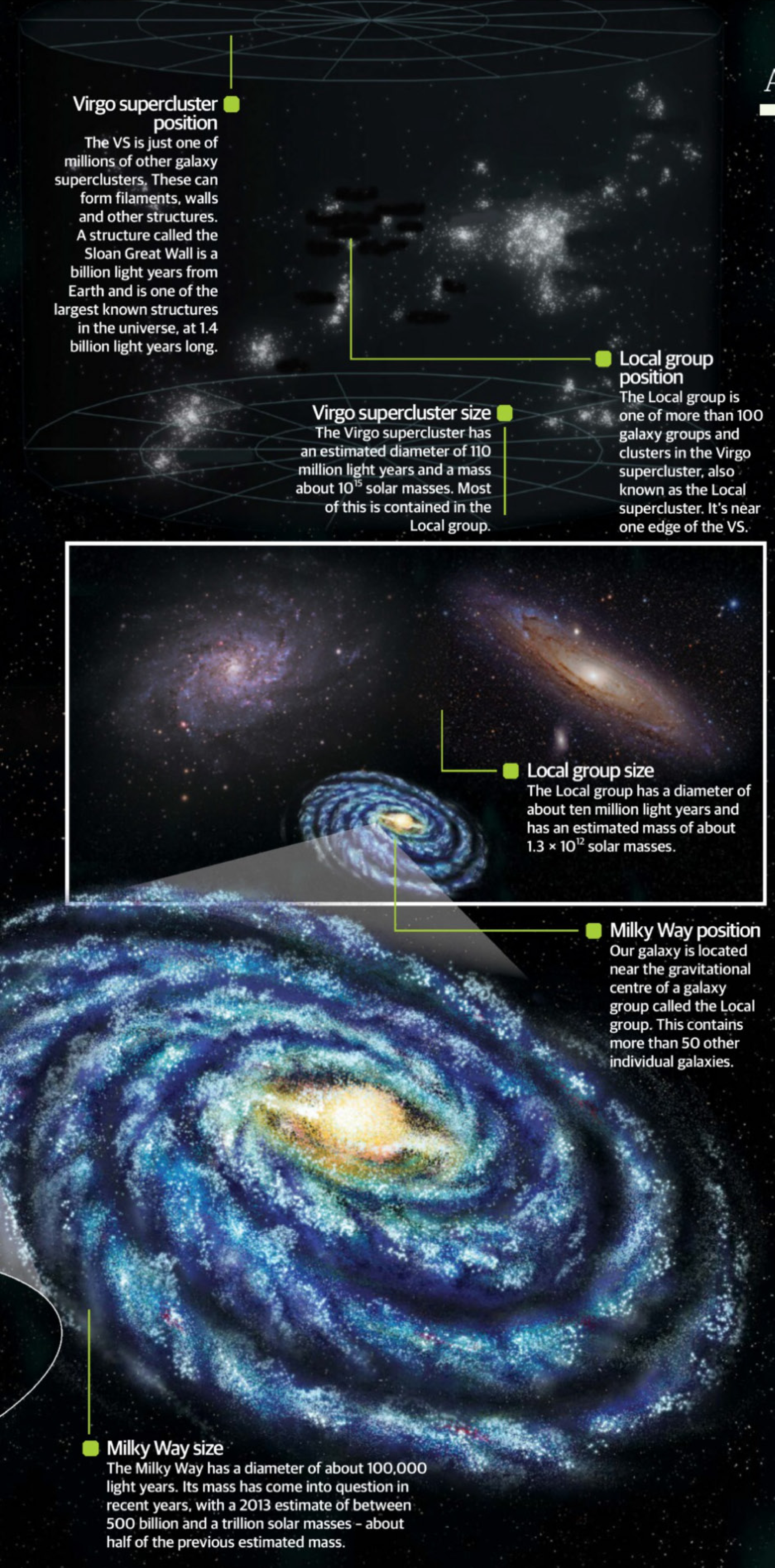
The Norma cluster is about 220 million light years away and is the centre of a gravitational anomaly called the Great Attractor. One suggestion is that there's something beyond our observable universe doing the pulling called the dark flow.

> "Our own galaxy is just one of thousands in the Virgo supercluster"

Solar System size
The outermost planet, Neptune, has an average orbit of 4.5 billion kilometres (2.8 billion miles or 4.2 light hours). The termination shock, or point at which a spaceship is said to leave the Solar System, is just over 12 billion kilometres (7.4 billion miles or 11 light hours). Our Solar System has a mass that is 1.0014 solar masses. A solar mass is 2×10^{30} kilograms (4.4×10^{30} pounds).

Earth size
The Earth has a diameter of 12,742 kilometres (7,918 miles) and a mass of 5.97×10^{24} kilograms (1.32×10^{25} pounds).

Earth position
The Earth's average distance from the Sun is 150 million kilometres (93 million miles) and it's the third of the inner planets.



Virgo supercluster position
The VS is just one of millions of other galaxy superclusters. These can form filaments, walls and other structures. A structure called the Sloan Great Wall is a billion light years from Earth and is one of the largest known structures in the universe, at 1.4 billion light years long.

Local group position
The Local group is one of more than 100 galaxy groups and clusters in the Virgo supercluster, also known as the Local supercluster. It's near one edge of the VS.

Virgo supercluster size
The Virgo supercluster has an estimated diameter of 110 million light years and a mass about 10^{15} solar masses. Most of this is contained in the Local group.

Local group size
The Local group has a diameter of about ten million light years and has an estimated mass of about 1.3×10^{12} solar masses.

Milky Way position
Our galaxy is located near the gravitational centre of a galaxy group called the Local group. This contains more than 50 other individual galaxies.

Milky Way size
The Milky Way has a diameter of about 100,000 light years. Its mass has come into question in recent years, with a 2013 estimate of between 500 billion and a trillion solar masses – about half of the previous estimated mass.

By the numbers

110 million light years

The distance spanned by the Virgo supercluster.

7,000

The VS is about 7,000 times the volume of the Local group.

100

There are at least 100 galaxy clusters and galaxy groups in the VS – each of them containing around 50 to 1,000 galaxies.

3.2×10^6 light years

Or one megaparsec – the thickness of the flattened disk in the VS that contains most of its galaxies.

3×10^{12} solar luminosity

The VS's total optical luminosity as compared to the Sun's luminosity.

Quadrillion

The mass of the Virgo supercluster is about a quadrillion times that of the Sun's mass.

373 miles per second

The speed at which VS is heading towards the Great Attractor.

100 Billion

The volume of the VS is 100 billion times that of the Milky Way.

Inside the Virgo supercluster

Take a look inside this intricate web of galaxies and clusters spanning millions of light years across

The VS is home to more than 100 galaxy clusters and galaxy groups, but most are considered rather small and minor. The Local and Virgo are the two largest clusters – the former is located on the outskirts of the VS and the Virgo cluster is at the supercluster's centre. In addition to the Milky Way, the other major galaxies in the Local group are the Andromeda and the Triangulum galaxies. The Milky Way and Andromeda are both massive, barred (containing a central bar structure) and spiral-armed. The latter is also the larger of the two and contains twice as many stars, but it's not believed to be as massive.

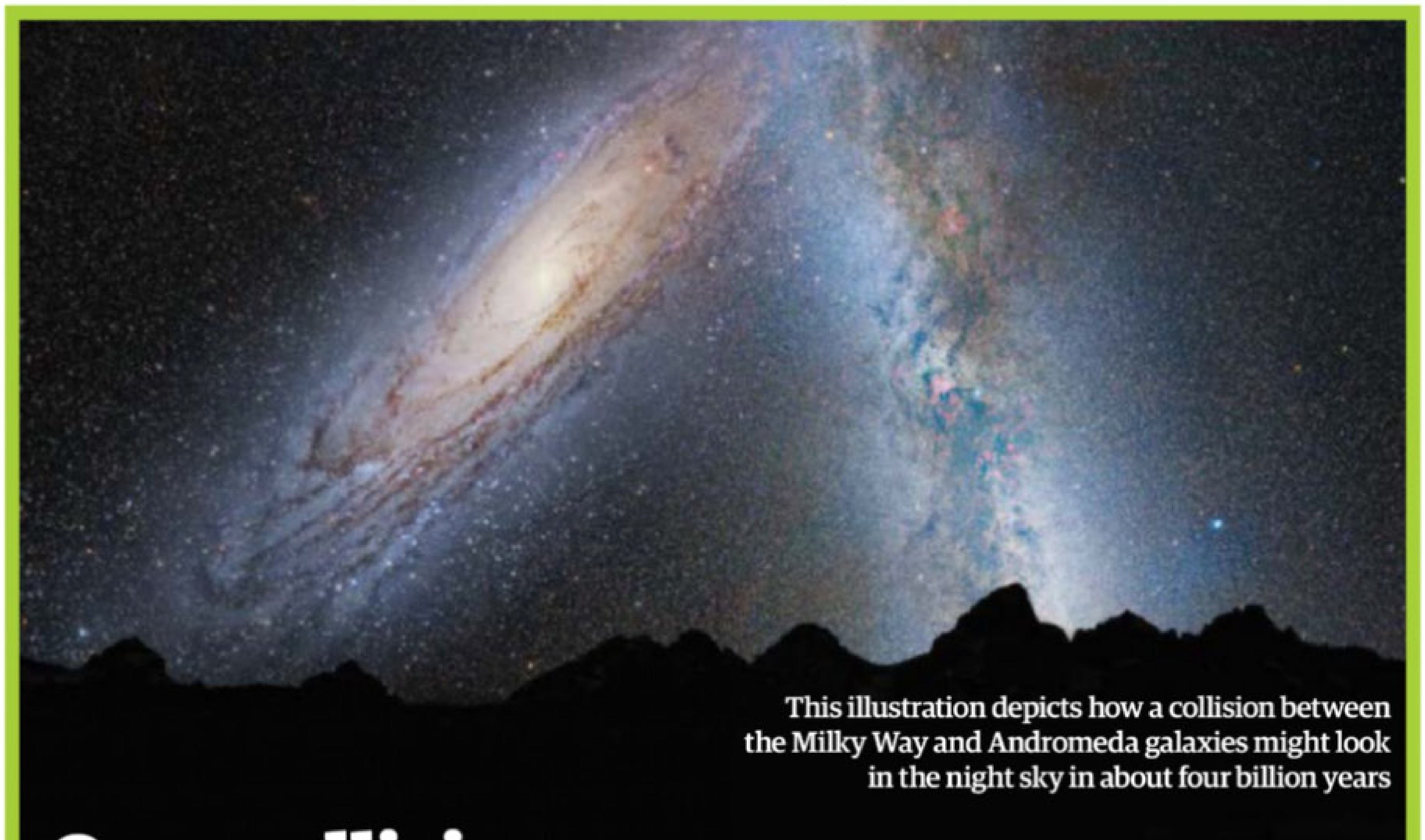
Both these galaxies have numerous smaller galaxies around them – some in orbit and others just nearby – each with their own characteristics and interactions with one another. The Milky Way has between 14 and 26 small orbit galaxies, while Andromeda has at least 24. Some of these companion galaxies contain very old stars, while others are considered young by comparison and stars are continuing to form all the time. Some galaxies, such as the Large Magellanic Cloud (LMC) around the Milky Way galaxy, are considered irregular galaxies – they have no distinct shape. However, the LMC may have previously been a spiral-armed galaxy and was disturbed by interactions with the Milky Way and the nearby Small Magellanic Cloud (SMC). The LMC and SMC are also both visible from Earth. Also in orbit around the Milky Way is the object considered to have an unusually high concentration of dark matter – the Draco Dwarf galaxy.

The Andromeda galaxy can be seen from Earth because it's so bright – visible to the naked eye when it's viewed during a new Moon. It also has a very bright orbiting galaxy visible from Earth: a dwarf elliptical galaxy called M32. Astronomers believe that Andromeda's satellite galaxies mostly align on a plane that passes through the centre of the galaxy – a curious finding that doesn't mesh with the current understanding of how galaxies form. The third largest galaxy, Triangulum, may be a satellite of Andromeda – it's an unbarred spiral galaxy and considered one of the most distant objects you can view from the Earth without a telescope or binoculars, at about three million light years away. As for companions, the Pisces Dwarf galaxy could be a satellite of Triangulum, but it might also be a satellite of Andromeda. Secluded from both Andromeda and the Milky Way are ten additional galaxy groups.

At the heart of the Virgo supercluster is its namesake, the Virgo cluster, located in the Virgo constellation. It contains around 1,500 galaxies that distribute fairly uniformly. Within this are three subgroups, or subclumps, called Virgo A, Virgo B and Virgo C, each centring on a separate elliptical galaxy. The most dominant is Virgo A, centred on M87. This galaxy has a supergiant black hole at its centre that has a mass estimated to be 3.5×10^9 times that of the Sun, believed to be one of the highest black hole masses in the known universe. It's also apparent that the three subclumps in the Virgo cluster are merging into one and that the cluster is still forming. Because it's so massive, the Virgo cluster heavily influences other galaxy groups and clusters in the supercluster and slows down their movement.

Although it's impossible to talk about all of the other galaxy groups and clusters in the VS, the M81 group is significant because it's one of the the closest to the Local group. Unlike our native group, however, this group is a very loose conglomeration of galaxies, some of which are so weakly bound that they don't even orbit around the centre, giving the appearance of a cloud. This makes identifying the brightest of the galaxies difficult, because it can be hard to determine which galaxies are members. ■

> "The Andromeda galaxy is visible from Earth because it's so bright"



This illustration depicts how a collision between the Milky Way and Andromeda galaxies might look in the night sky in about four billion years

On a collision course

Some galaxies in the Local group are set to collide with others, or have collided in the past. Collisions are common in galaxy groups because of gravitational attraction and often result in the formation of larger galaxies, or at the very least alterations of their structures or orbits.

For example, the Sagittarius Dwarf Spherioidal galaxy will probably collide with the Milky Way if it maintains its current course, but some astronomers believe that such a collision has happened before and could be at least partially responsible for the spiral arm structure of our native galaxy.

Collisions between two smaller galaxies have also resulted in larger ones being produced – the Andromeda galaxy probably formed this way. The Milky Way and Andromeda may themselves collide in about four billion years. While it's unlikely that any stars will actually collide, the galaxies themselves merge to form a giant elliptical galaxy and the supermassive black holes at their centres converge.

Inside the Virgo supercluster

The most luminous galaxies in the Virgo supercluster are contained in just 11 galaxy groups and clusters

Milky Way galaxy
Our Milky Way contains between 100 and 400 billion stars, with potentially just as many planets.

M101 group
This loose group of galaxies is known for the very bright Pinwheel galaxy (M101), a face-on spiral galaxy extensively photographed by the Hubble Space Telescope.

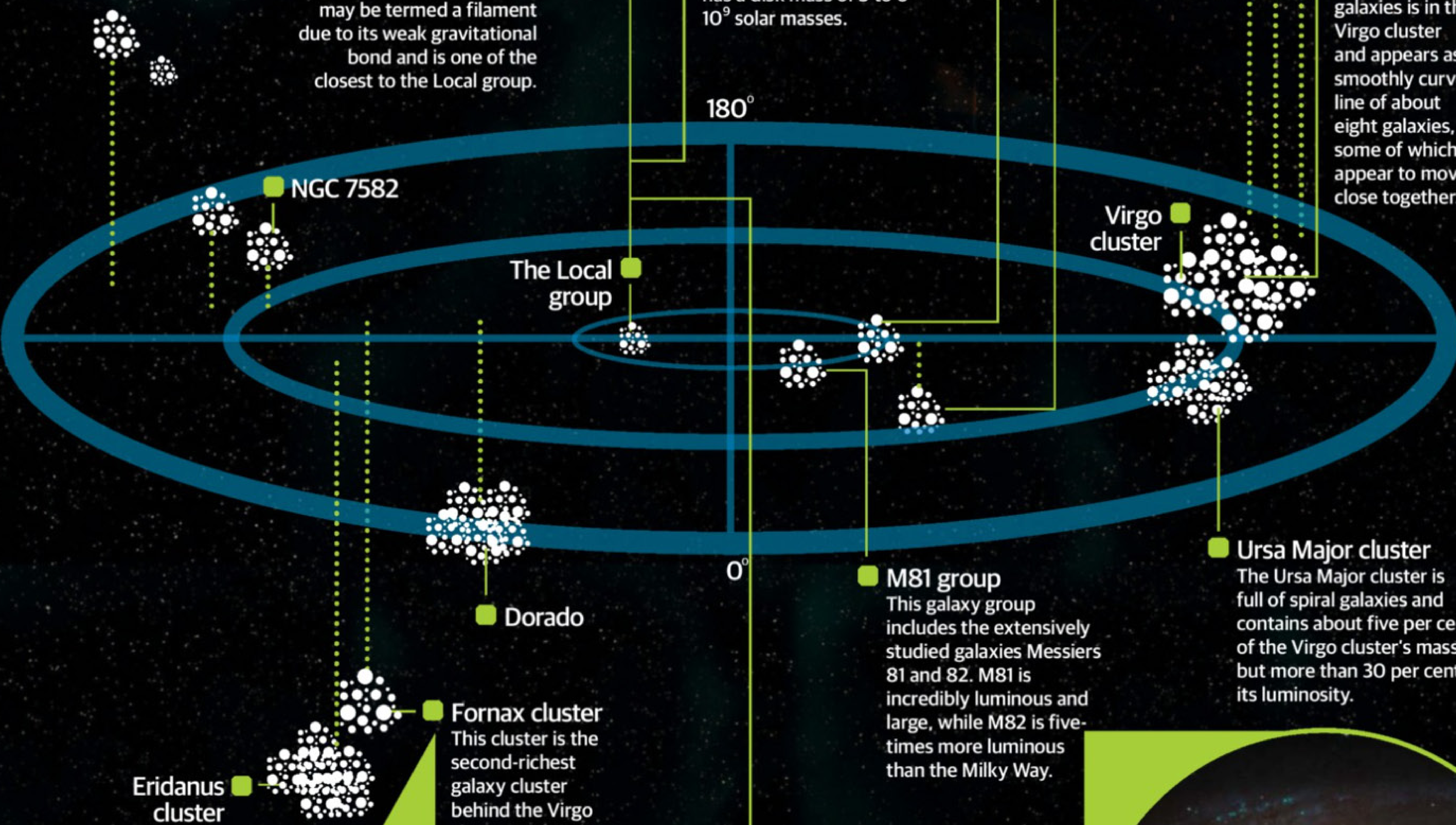
Leo I group
Also known as the M96 group, is a collection of between eight and 24 galaxies in the constellation of Leo, including the Messier objects M95, M96 and M105.

Sculptor group
This loose group of galaxies may be termed a filament due to its weak gravitational bond and is one of the closest to the Local group.

Triangulum galaxy
The Triangulum galaxy has about 40 billion stars and has a disk mass of 3 to 6 × 10^9 solar masses.

Virgo III groups

Markarian's chain
This chain of galaxies is in the Virgo cluster and appears as a smoothly curved line of about eight galaxies, some of which appear to move close together.

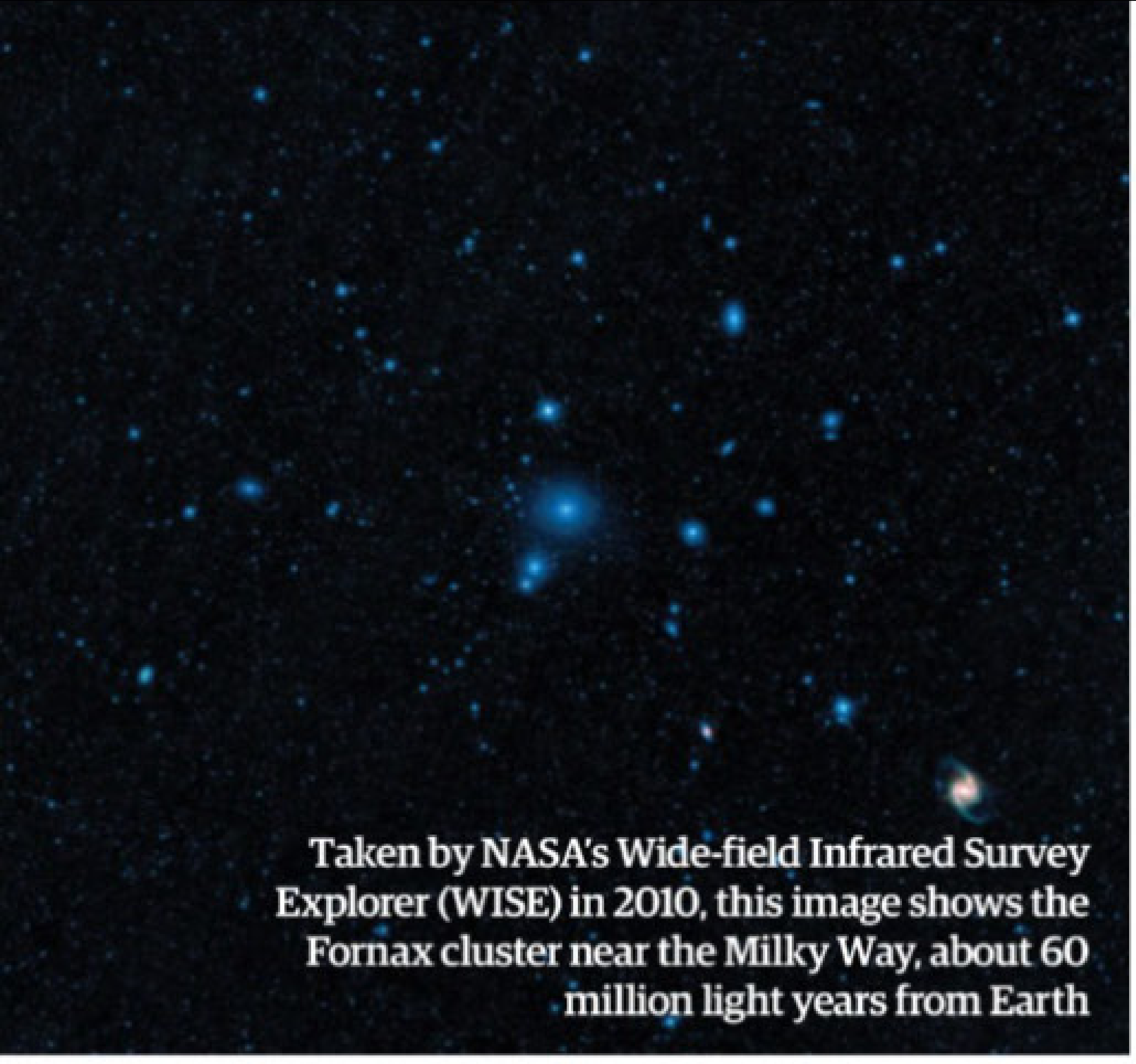


M81 group
This galaxy group includes the extensively studied galaxies Messiers 81 and 82. M81 is incredibly luminous and large, while M82 is five-times more luminous than the Milky Way.

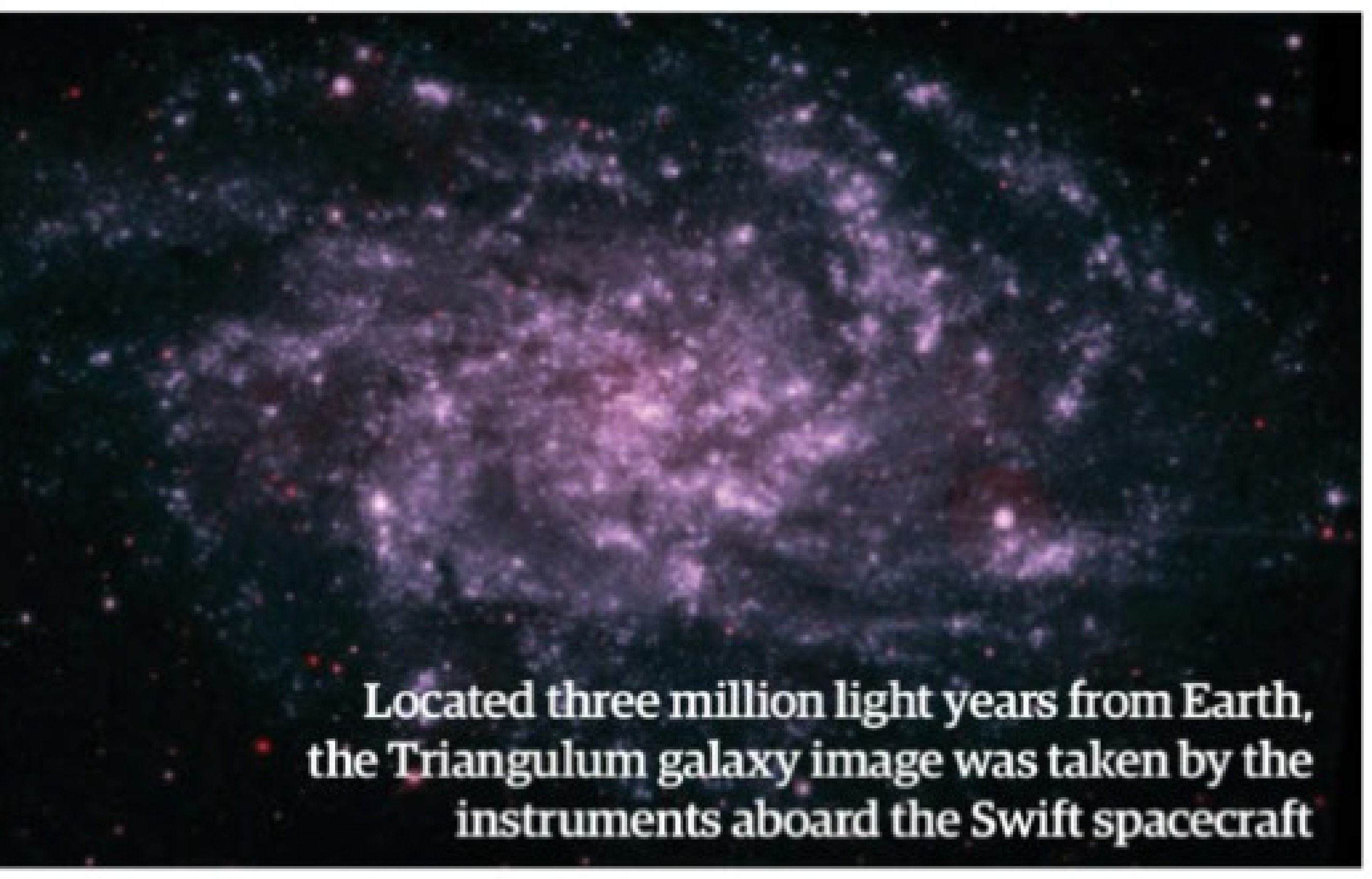
Ursa Major cluster
The Ursa Major cluster is full of spiral galaxies and contains about five per cent of the Virgo cluster's mass, but more than 30 per cent of its luminosity.

Fornax cluster
This cluster is the second-richest galaxy cluster behind the Virgo cluster, with at least 50 galaxies. There is evidence of strong star formation here.

Andromeda galaxy
The Andromeda galaxy could contain as many as a trillion stars and appears six-times wider than the Moon in our night sky.



Taken by NASA's Wide-field Infrared Survey Explorer (WISE) in 2010, this image shows the Fornax cluster near the Milky Way, about 60 million light years from Earth



Located three million light years from Earth, the Triangulum galaxy image was taken by the instruments aboard the Swift spacecraft

Taken from Earth, this image shows the tiny dwarf spheroidal galaxy Leo I as a faint patch to the right of the bright star Regulus

Captured by Swift, this image of the Andromeda galaxy 2.5 million light years away is the highest-resolution view of a spiral galaxy ever attained in ultraviolet

Observing Virgo

The origins and future of exploring the supercluster

The Virgo supercluster has only been known by this name since the 1950s – and it's been a long journey from its initial observation to what we know today. Astronomer Charles Messier, author of the *Messier Astronomical Catalogue of Nebulae and Star Clusters*, noted that there were many nebulae near the edge of the Virgo constellation. At the time, the term 'nebula' (an interstellar cloud of dust and gas) was used to describe any kind of cloud-like astronomical object.

Pioneering astronomers John and William Herschel also observed the nebulae and published a study in 1864. Harlow Shapley and Adelaide Ames first used the term 'cluster', calling the galaxies they observed a 'cluster of bright spiral nebulae', in the late 1920s. Then Edwin Hubble and M.L. Humason classified some of the galaxies in the region as belonging to the Virgo cluster in 1931.

The VS began to be better understood in 1958, due to the work of astronomer Gérard Henri de Vaucouleurs. He argued that these galaxy clusters are grouped into even larger clusters – superclusters – due to gravitational attraction. He first called the Virgo supercluster the Local supergalaxy and later the Local supercluster, the latter of which is still used as a name for it. Initially Vaucouleurs' theories were controversial and astronomers continued to debate about whether the supercluster could be an organised structure, or if the proximity was just coincidental.

> "The VS is a somewhat flat, gravitationally bound structure"

The debate all but ended with redshift surveys conducted in the 1970s and 1980s, the first of which was the CfA Redshift Surveys that began in 1977. These surveys measured the redshift of an astronomical object to create a 3D map of a particular section of sky. The data could be used to determine the distance of galaxies and make measurements of the largest objects in the observable universe. A galaxy's redshift (or blueshift, if it's moving towards us) is the way that its spectral features shift to longer (or shorter) wavelengths.

Both the expansion of the universe (the Hubble Flow) and Doppler motions trigger these changes in the wavelengths caused by the motion of the object itself. Ultimately these surveys proved that the Virgo supercluster is a flat, gravitationally bound structure consisting of galaxy groups and clusters. They also showed that the universe has a honeycomb-like structure of filaments, sheets and walls of galaxies.

Many of the most powerful telescopes in the world, including the Large Binocular Telescope (right), have spent time studying the features of the VS. But it's impossible to discuss observations of this supercluster without mentioning the Hubble Space Telescope (HST). Launched in 1990, the HST has given us some of the most iconic images of different galaxies in the VS. This includes the largest and most detailed HD portrait of a spiral galaxy – a stunning image of the Pinwheel galaxy (M101). It has also shown us new galaxies and determined their place in the supercluster. For example, studies of HST observations have shown that the Large Magellanic Cloud and Small Magellanic Cloud, believed to be orbiting the Milky Way, might be moving too fast to be more than just passing through.

On land, the Keck Observatory's twin telescopes are among the most powerful in the world. Among its recent observations in the supercluster is both one of the smallest and the most significant. In June 2013, it revealed more information about one of the tiniest galaxies – Segue 2 located in the Milky Way. With just 1,000 stars and a small globule of dark matter, this very faint galaxy may reveal more about how galaxies form. This just goes to show that while the Virgo supercluster may be just one out of millions, it's still revealing vast amounts of information about our universe as a whole. ■

Large Binocular Telescope (LBT)

First observation
The first image from the LBT was NGC 891, an edge-on spiral galaxy in the NGC 1023 group located in the Canes Venatici cloud of the VS.

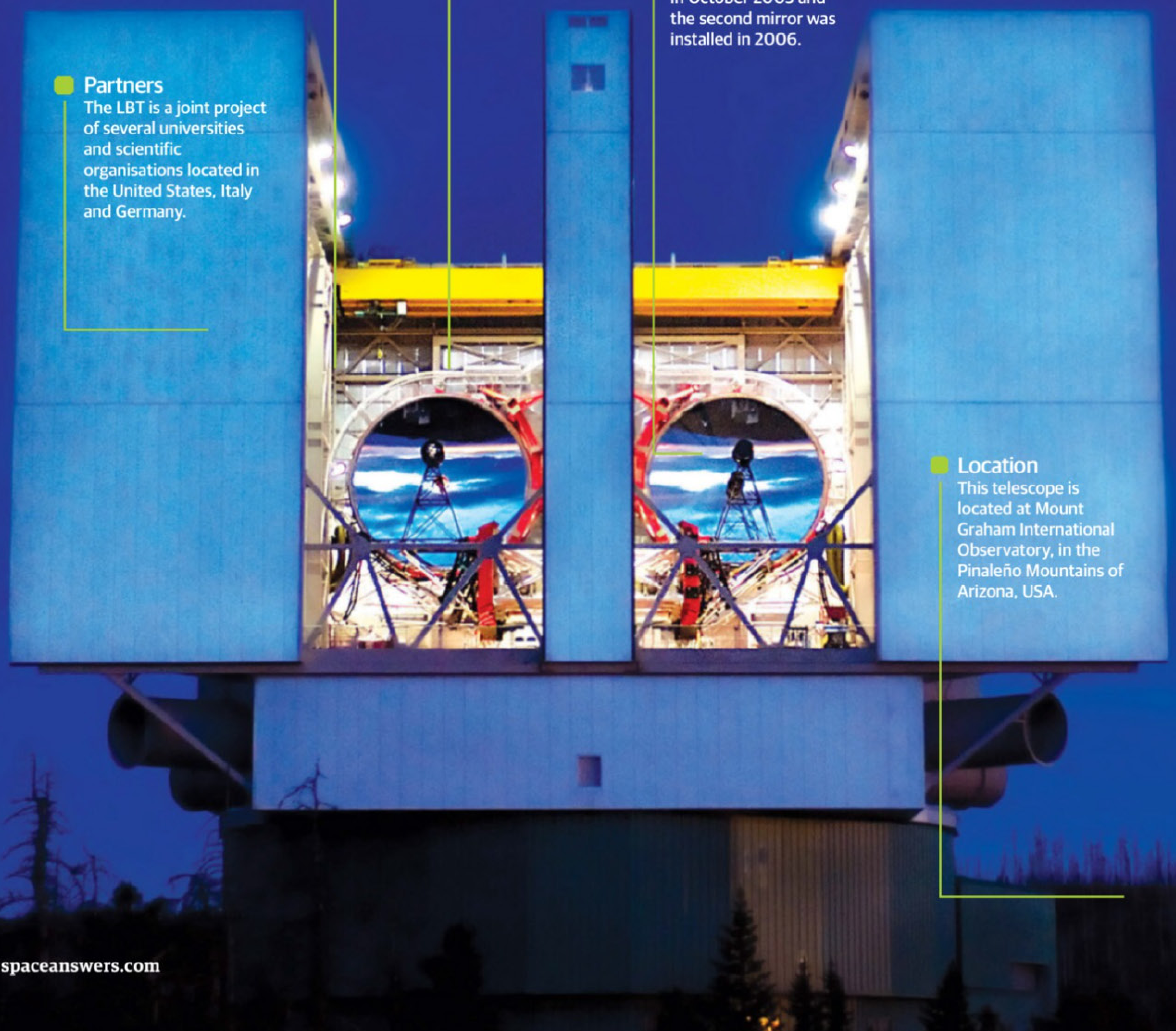
Star formation
The LBT's observations of the Trapezium region in Orion have revealed the positions of young stars in their orbits and confirmed a theory about the nature of star formation.

The LBT is a collaborative project between institutions based in the USA, Italy and Germany

Mirrors
The LBT has two 8.4-metre- (27.6-foot-) wide mirrors that are separated in the centre by 14.4 metres (47.2 feet) and an adaptive mirror to correct distortion.

Prime focus camera
Looking at Messier 81 in the M81 Group using the UV-blue camera revealed the faint dwarf galaxy Holmberg IX.

Installation
The LBT saw first light with a single mirror in October 2005 and the second mirror was installed in 2006.



Partners
The LBT is a joint project of several universities and scientific organisations located in the United States, Italy and Germany.

Location
This telescope is located at Mount Graham International Observatory, in the Pinaleño Mountains of Arizona, USA.

© Getty Images; NASA; Sayo Studio; Adam Evans; Hewholooks; Andrew Z. Colvin; 2MASS; ESA; JPL-Caltech/UCLA; Bill Schoening, Vanessa Harvey; REU program; NOAO; AURA; NSF; Hubble; Scott AnttilaAnttler;

The Rosetta Mission Control team at the European Space Operations Centre (ESOC) on 4 March 2004, two days after Rosetta launched

Landing on a speeding comet

Since 1985 Dr. Gerhard Schwehm has waited for an unprecedented mission to a comet's surface and now, after almost 30 years of work, his dream will finally be realised with ESA's Rosetta mission

Interviewed by Jonathan O'Callaghan

INTERVIEWBIO

Dr. Gerhard Schwehm

In 1985 German-born Dr. Gerhard Schwehm became the lead scientist on ESA's Rosetta mission. At first the mission was intended to return a sample from a comet but, when NASA withdrew support as a partner, ESA was forced to go it alone and redesign the mission, which finally launched on 2 March 2004.

What is the main goal of the Rosetta mission?

There are three main goals, but most of all it's a mission to study a comet. Since the Halley flybys in 1986 we've learnt a lot about comets from in-situ measurements, but there are still a number of questions open. We know that the comet [67P] is outgassing, but we don't know why and also we really don't understand the structure of the comet.

One objective is to study the physics of the comet, how it works and why the ices start to sublimate. We want to go into more detail and the big advantage of Rosetta is we can monitor it over a long path of the comet's orbit. We'll start to observe it when the activity is fairly low and then we'll go through perihelion [the closest point to the Sun] and the activity will increase as we get closer to the Sun because the comet is hotter. Then we'll also travel away from the Sun with the comet, so we'll see the changes when it recedes.

What else do you hope to learn from the mission?

The most important objective of the mission, as comets are the most primitive objects that are accessible to us for direct study, is to look back into the early stages of the pre-solar nebula, the time when the planets and the Sun formed.

The material in the comets is the most unaltered that's accessible to us, so we can basically look back into the infancy of our Solar System. The other goal is to learn more about how life possibly evolved on

Earth, to get some idea of the steps between having very complex molecules and then going to the start of life. We won't find life on comets, but we know that there are very complex molecules in them. We know that there's organic material and we know from meteorites that there are amino acids to be found. It's a whole exciting field of complex chemistry that we will tackle with new results that we can get from the Rosetta spacecraft.

What will the Rosetta mission do that has never been done before?

First of all we will monitor the activity of a comet over a very long time, about two years, which means we will understand how the comet works. Second, using the very sophisticated instruments we have on board, we can study the composition of the material that's released by the nucleus.

We'll also land on the surface of a comet for the first time. We'll take samples down to a depth of 40 centimetres (15.7 inches), if we are lucky, so we can get some material that's below the surface. We should also have the opportunity to look for isotropic glaciers of water. One of the big questions is whether or not comets brought water onto the early Earth. There's an instrument from the Open University that's focusing on these isotropic glaciers, that will really give us new insight into the question of water in comets and the link to water on Earth.

Personally, what are you most looking forward to from the mission?

I'm looking forward to the dust measurements and I hope that we can see if we have purely organic grain, as we saw with the instruments we had on the Giotto and Vega spacecraft [in the 1980s]. Another is the detailed study of the gases released from the comet and the composition of these gases, which I believe will give us some ideas as to where the material formed and under what conditions in the pre-solar nebula. This should provide a lot of new data and new parameters that can help us understand the evolution of the planets.

Last but not least we have a high-resolution wide-angle camera system on board and we can see how the comet really works on the surface with the highest resolution, which is important for the public. We hope to reach resolutions of around ten centimetres (four inches) or even better and this is basically an order of magnitude better than what we have today. The closer you get, the more you learn. If the [Philae] lander is successful on the surface, we even have a microscope through which we can survey and see structures on the sub-centimetre scale, going down with the atomic force telescope to the nanometre scale of the dust range. This will be really fascinating, I think.

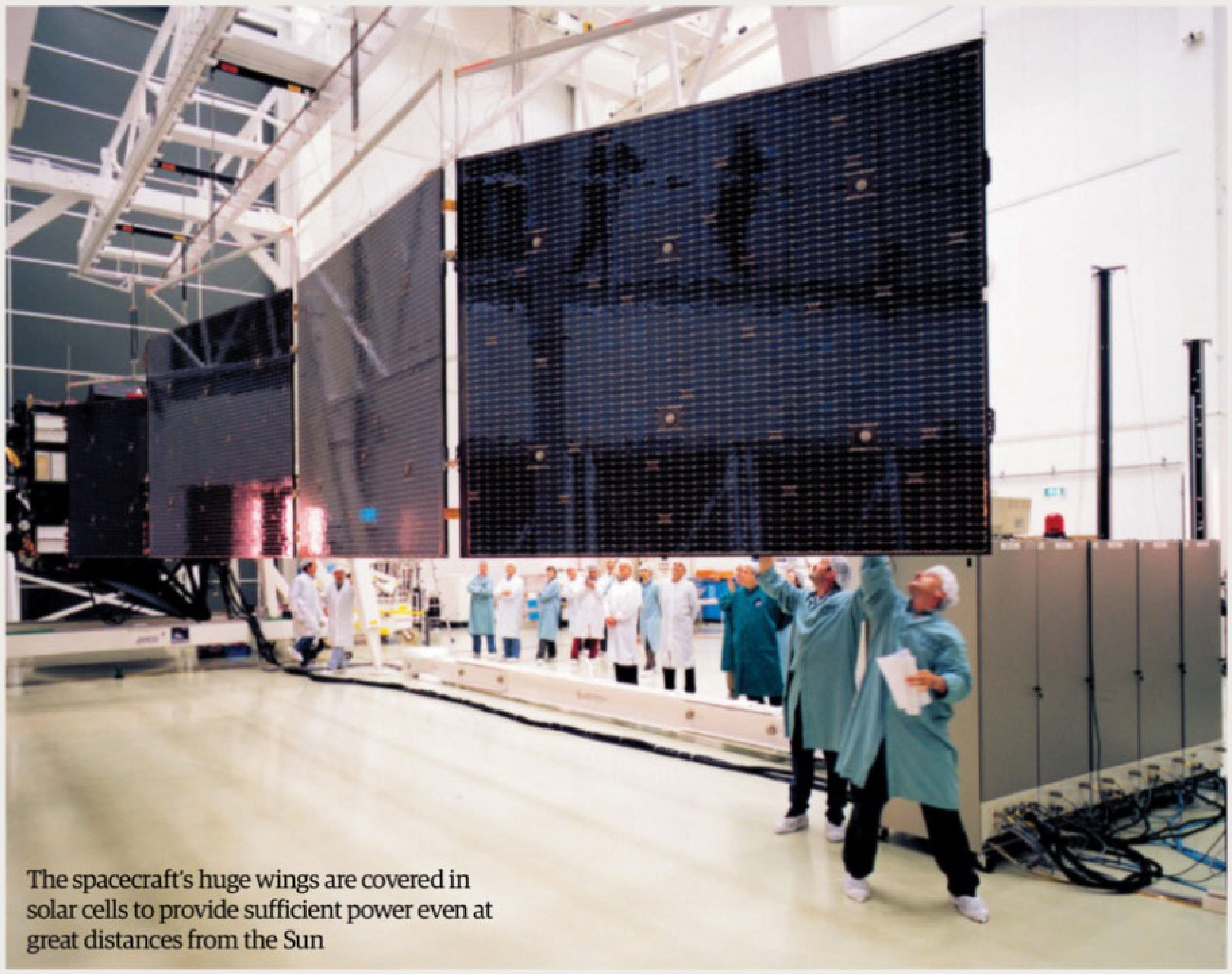
What's the time frame for Rosetta approaching the comet?

At the end of May [2014] the last big orbit manoeuvre will begin and we can synchronise the orbit of the spacecraft with that of the comet. Then we should be very close, just a couple of thousand kilometres away, and we'll approach the comet. We will go into the first orbit around 50 to 70 kilometres (31 to 43 miles) from the surface, depending on the activity of the comet, so that gives us a better look. Also the density of the material will increase, which increases the signature noise for our spectrometers, so we will learn a lot on this orbit.

We can map the comet from orbit to give us great images of the surface for the first time, where we can observe the whole surface in infrared. We can start the detailed mapping of the nucleus in August, September and October and in November we will release the lander to perform its measurements on the surface. As soon as the lander is on the surface we'll start the fully fledged monitoring of the comet nucleus with all of the instruments. You know, I really think whatever we do, we will learn a lot of new things, because it's the first time we've ever put a lander on a comet and it's the first time we'll have a spacecraft in orbit around a comet. So we are really confident that we will get new things, new questions coming up, new results that will help us either to confirm some of the theories or ask new questions.

The Philae lander itself is quite a big undertaking, how will it work?

As I said, we will map the comet's surface to high resolution in August and September, so at the end of September the lander team has to tell us what their preferred landing site is. Then my colleagues from Flight Dynamics in ESOC [European Space Operations Centre] need to prepare the whole deployment scenario – effectively what orbit the spacecraft has to fly. We can then deploy the lander in mid-November and then it goes down to the



The spacecraft's huge wings are covered in solar cells to provide sufficient power even at great distances from the Sun

The Philae lander will use harpoons and ice screws to keep itself attached to the comet's surface

The Rosetta team breaks into celebration at the ESA control centre in Darmstadt, Germany as a signal from the spacecraft is successfully received after 31 months of hibernation on 20 January 2014

“The lander shouldn’t take much longer than two hours to touch the surface”

surface. What will happen is that the [Rosetta] spacecraft will fly a certain approach manoeuvre to reach a point that the lander can be released with very high accuracy, because you have to realise the lander is more or less passive.

The lander will be pushed at about 30 centimetres (11.8 inches) per second and in general terms will fall down onto the comet nucleus surface. Even if the gravitational attraction involved is extremely minimal, the lander will basically fall down because we'll release it against the orbital velocity of the orbiting spacecraft.

After a certain time the three legs will unfold and as soon as two of the legs touch the surface two harpoons fire into the surface of the nucleus to basically anchor the lander. In each of the three legs we have what we call ice screws, so just by the force that is exerted when the feet touch the surface of the nucleus, these screws will go into the upper layer of the nucleus and that should be enough to anchor the lander onto the surface.

It seems quite complicated, how confident are you that it will work?

This is the first time that this has been done and with a comet it's much more complicated than, for example, landing on an asteroid. It'll be done more or less with a lander that doesn't have it's own attitude system, so it's passive.

Our colleagues from Germany and France have tested it as much as possible, simulating the approach, so I'm confident that it will work. As a caveat: if the comet is very active, then we have to stay a little further away from the surface and then the flight time would be longer and the disturbances from the ejected gas from the nucleus could disturb the flight path. This is an uncertainty we have, so we want to release it as close as possible to minimise the flight time.

I have been following this from the beginning, with all the ups and downs, so I'm confident that it will work. Hopefully the lander shouldn't take much longer than two hours to touch the surface from the release, which could prove to be a nail-biting two hours I can tell you.

This is also the first spacecraft to rely solely on solar power out to the distance of Jupiter, why was this engineering decision made?

The decision was made out of sheer necessity. When we couldn't do the comet sample return mission, which was a joint mission with NASA, we had to have a mission that could be done by Europe alone under our leadership. That meant we would have no RTGs [Radioisotope Thermoelectric Generators] available to us, which is what NASA spacecraft use when they go to Jupiter or beyond. We don't have RTG technology in Europe, so that means they would have to be provided by NASA. This would mean NASA having to launch the spacecraft, because RTGs fall under its jurisdiction so they can only be launched from the US.

So, with that decision to go with a European-led mission, we had to find a way to power the spacecraft and that could only be done with solar arrays, because you can't develop RTGs within a very short time span. ESA is now looking into developing a European version of RTGs, but at that time this was the only way to go. So we had to

Comet missions

12 Aug 1978

ICE

The International Cometary Explorer (ICE) was the first spacecraft sent to visit a comet.

15 and 21 Dec 1984

Vega 1 and 2

After dropping landers and balloons on Venus, the twin Vega spacecraft intercepted Halley's comet and returned images in early 1986.

7 Jan 1985

Sakigake

Japan's first interplanetary spacecraft became part of the so-called Halley Armada of spacecraft, flying past the comet on 11 March 1986.

2 Jul 1985

Giotto

ESA's Giotto spacecraft was sent to study Halley's Comet. It approached the nucleus of the comet to a distance of just 596 kilometres (370 miles).

19 Aug 1985

Suisei

The last of the Halley Armada was Japan's Suisei spacecraft, which approached the comet on 8 March 1986.

develop new low-intensity, low-temperature solar cells, because we're going far away from the Sun, where the solar intensity is only four per cent of what we receive in Earth orbit. Rosetta will also be at very low temperatures, but this was the only way to go, otherwise the mission wouldn't have been feasible.

How would the mission be different with RTGs?
It would have made the mission a little bit simpler to some extent, as well as avoiding the need for the spacecraft to go into hibernation for 31 months. This was because even with those huge solar arrays, we didn't have enough power to operate the spacecraft beyond 4.4 Astronomical Units [AU] from the Sun.

Very early on we took the decision that we would put the spacecraft under hibernation when we were far away from the Sun and wake it up again when we came closer, so that was what happened on 20 January this year. We have been testing it out and so far so good - now the next step is to test out the instruments and see how they managed through this long hibernation.

With the mission approaching its critical science phase, what is the feeling on the team?
Everybody is quite excited as you can imagine. [2 March] was the tenth anniversary of the launch and when you have a mission like this you want to go to the heart of the project, which is the phase where we are at the comet.

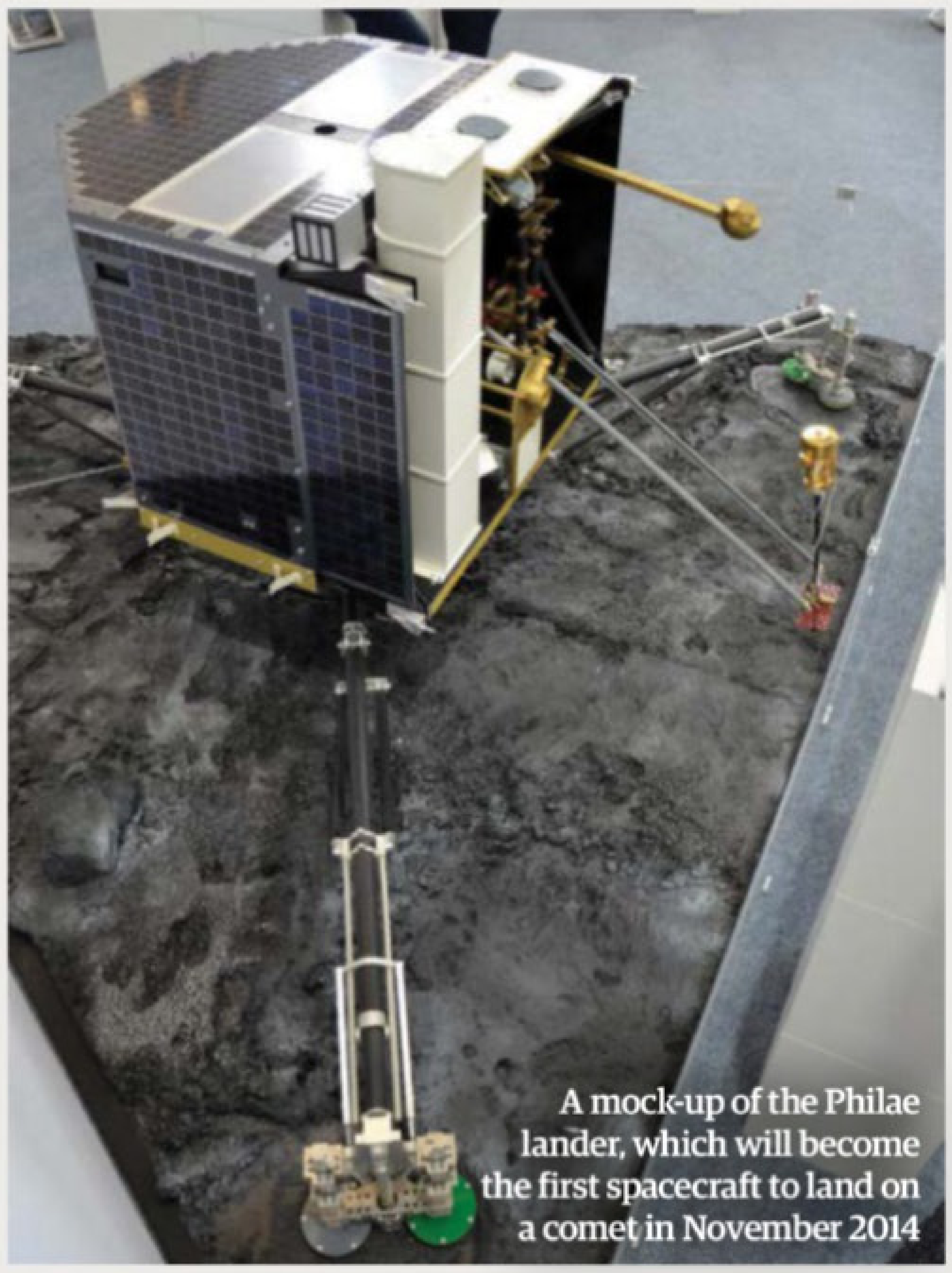
I have been on this project a long time, basically my whole career at ESA and you want to see that you get the results of all your investments. After some time the wait is enough, you want to get the results, you want to work on it. Now after the end of hibernation it's basically the kick-off of the comet phase for the mission and everybody is really excited to get the first results. Everybody knows that this will be two hard years in front of us and it's a lot of work, but this is what you want to get.

Looking beyond Rosetta, what's the next step?
The next big step would be what we wanted to do originally, which is to return a sample from a comet. My colleagues in NASA are studying a comet surface sample return and I'm looking forward to that.

Comets are much more diverse than we thought before we started the mission. Their surfaces look different and we know that there are two comet reservoirs, the Kuiper Belt objects and the Oort Cloud objects. Hopefully in a couple of decades we can look if there are crucial differences between the two classes of comets. This will be the long-term outlook, the next big step after Rosetta, but first we have to demonstrate that everything works. ■

Dr. Gerhard Schwehm

Dr. Schwehm (left) has been an outspoken proponent of missions to comets since 1985



A mock-up of the Philae lander, which will become the first spacecraft to land on a comet in November 2014

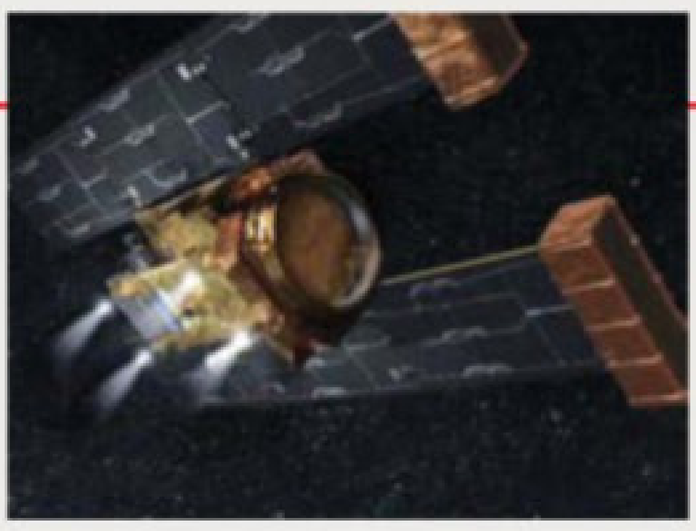
In 2007 Rosetta snapped this incredible image of one of its solar array wings, with Mars seen below

Rosetta was taken out of a 31-month hibernation ahead of its rendezvous with comet 67P

The Rosetta spacecraft lifted off aboard an Ariane 5 rocket on 2 March 2004

24 Oct 1998

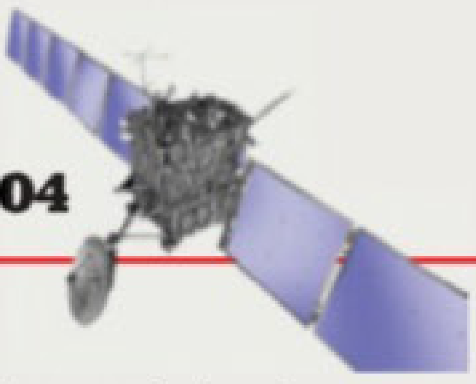
Deep Space 1
Designed to test risky tech, NASA's Deep Space 1 studied Borrelly's Comet in September 2001.



7 Feb 1999

Stardust
NASA's Stardust spacecraft was the first to collect dust samples from the coma of a comet, which were returned to Earth on 15 January 2006.

2 March 2004



Rosetta
Rosetta will not only be the first spacecraft to orbit with a comet but it will also be the first to directly study the surface of these icy rocks in late 2014.

12 Jan 2005

Deep Impact
NASA's Deep Impact space probe released an impactor into the comet 9P/Tempel on 4 July 2005, enabling photographs and studies of the impact crater to be taken.

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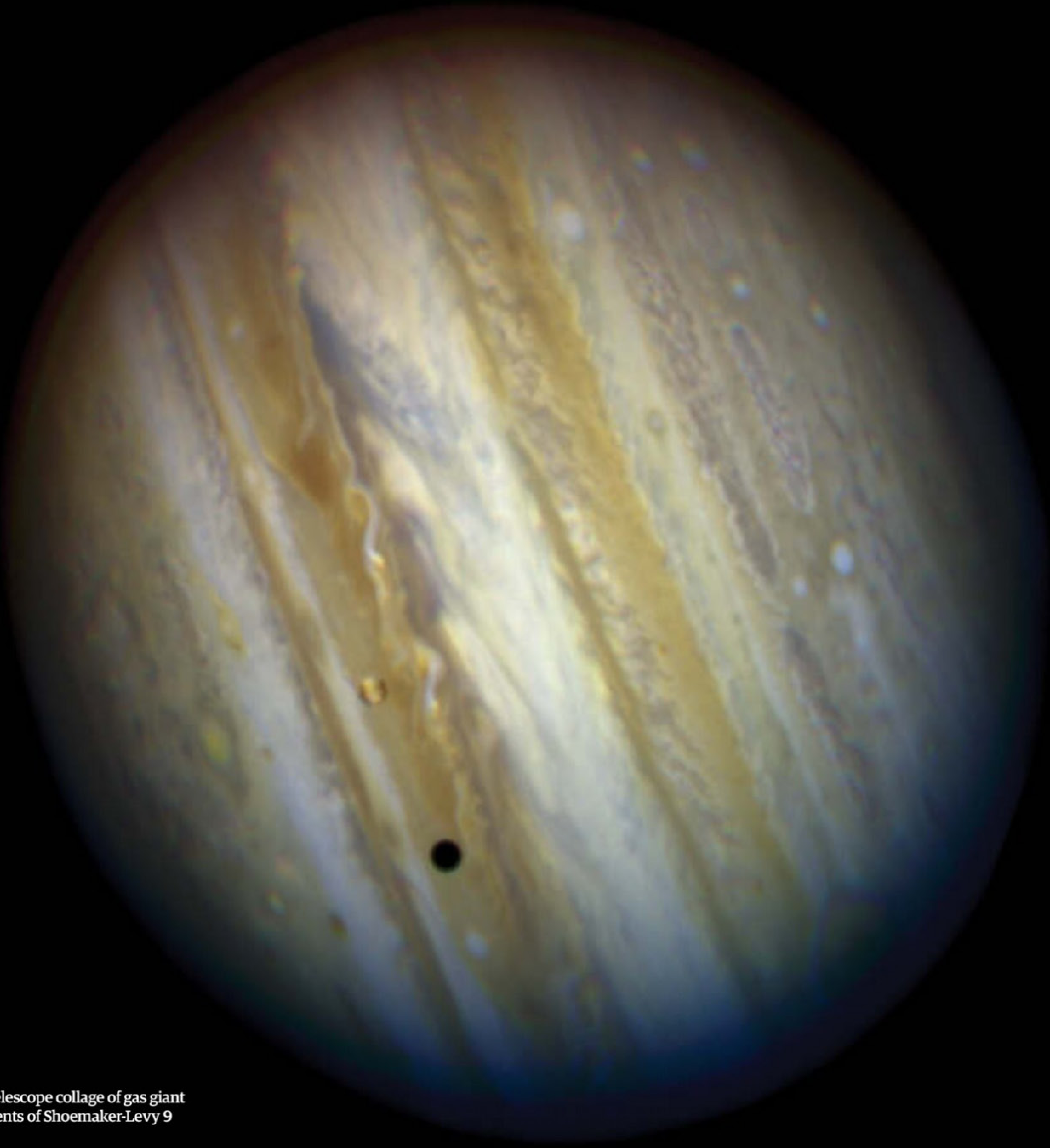
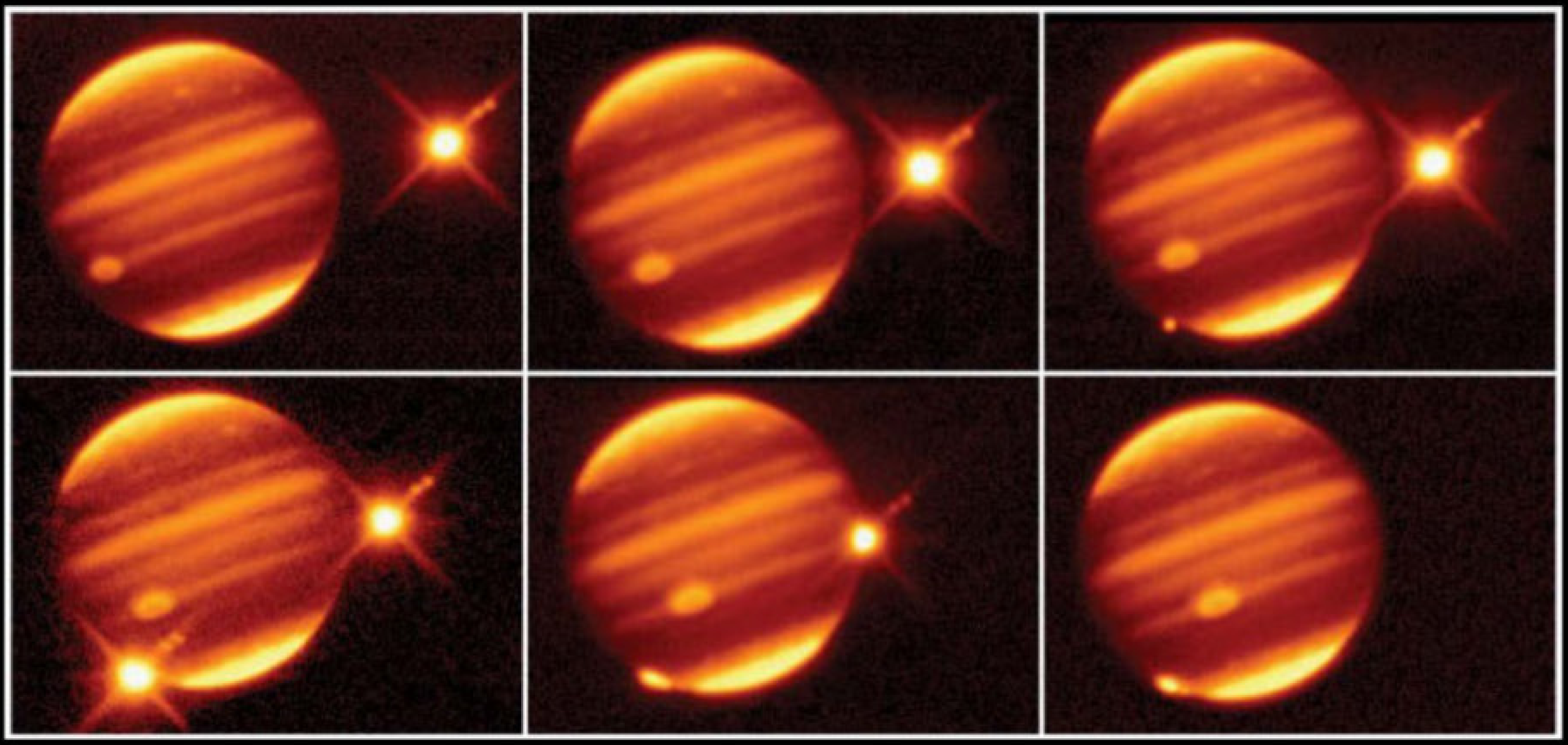


A Hubble Space Telescope collage of gas giant Jupiter and fragments of Shoemaker-Levy 9



An infrared sequence of events showing a fragment of Shoemaker-Levy 9 smashing into the surface of Jupiter

Shoemaker-Levy 9

It was the impact that excited the astronomical community and caused a media frenzy. Meet the comet that struck Jupiter

On a spring evening of 24 March 1993, Carolyn Shoemaker, Eugene Shoemaker and David Levy couldn't have imagined that the space snowball they had just spotted would create a tidal wave of media attention and excitement among astronomers over a year later.

By July 1994, comet Shoemaker-Levy 9 was finally due to break up. What's more, all that was left of it was going to smash into the king of the Solar System, Jupiter, in an impact that gave observers the first taste of an extraterrestrial collision between these Solar System bodies.

This didn't go unnoticed: astronomers trained their eyes on the orbit of their newfound comet and saw that Shoemaker-Levy 9 wasn't orbiting the Sun like the rest of the members of its distant travelling family. The comet was circling Jupiter, looking to fall into the giant planet's abyss of gases, ammonia and water vapour.

Getting close to the limbs of Jupiter wasn't anything new to Shoemaker-Levy. In July 1992 the comet had been swinging in an orbit about 42,200 kilometres (25,000 miles) above the gas giant's cloud tops, well within the orbit of the planet's innermost moon Metis. It soon became evident that the comet had suffered the consequences of its actions as Jupiter's devastating tidal forces had weakened Shoemaker-Levy 9, splitting it into fragments that smashed into the planet's surface at a staggering 215,652 kilometres (134,000 miles) per hour.

Shoemaker-Levy 9 might be no more but its legacy lived on in the bruises that it left behind in Jupiter's southern hemisphere. Astonishingly these were more easily visible than the planet's Great Red Spot for many months, according to astronomers' observations at the time.

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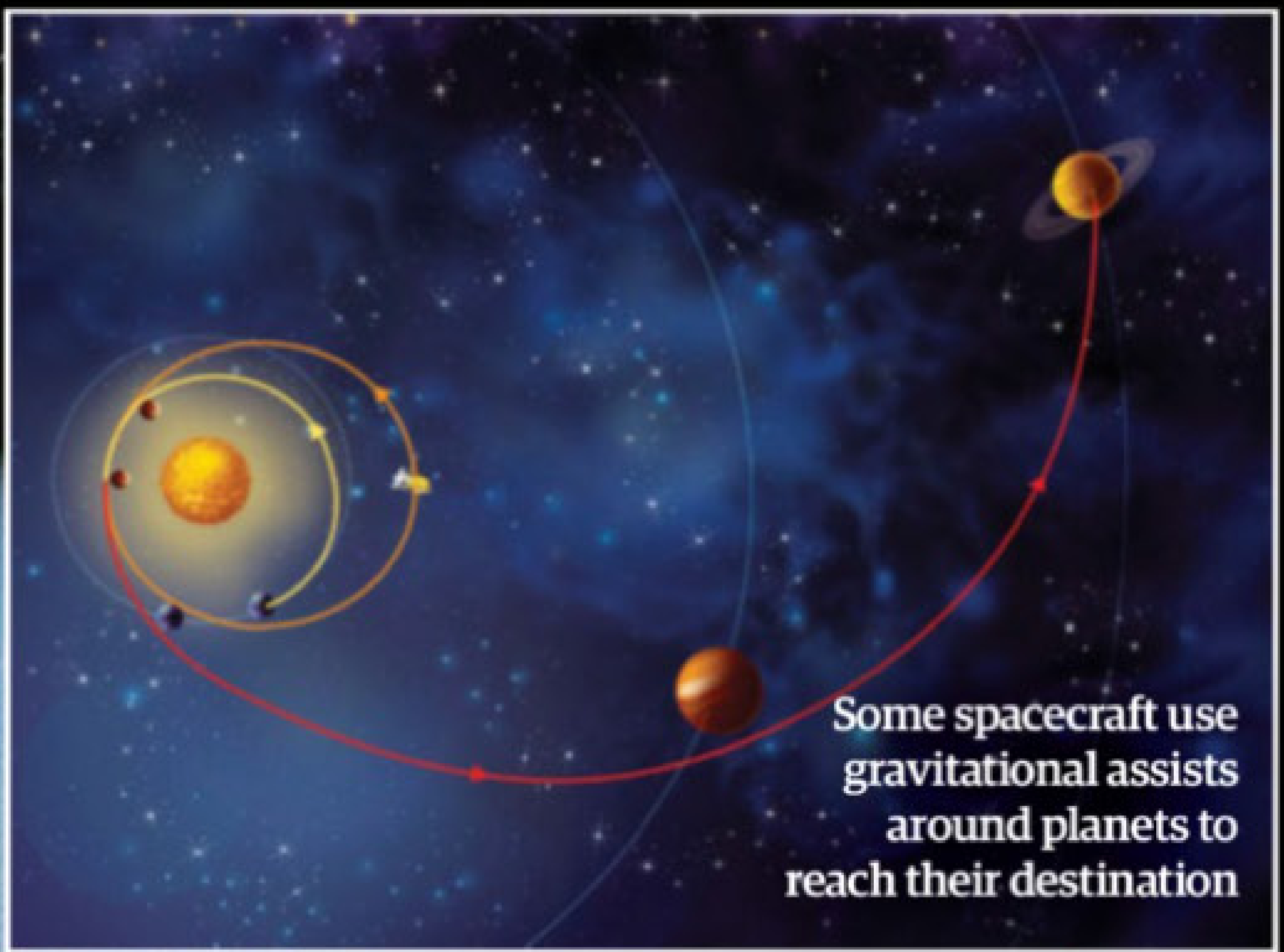
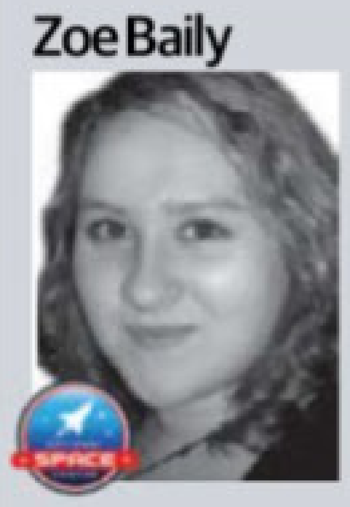


Some spacecraft use gravitational assists around planets to reach their destination

YOUR QUESTIONS ANSWERED BY OUR EXPERTS

In proud association with the National Space Centre *www.spacecentre.co.uk*

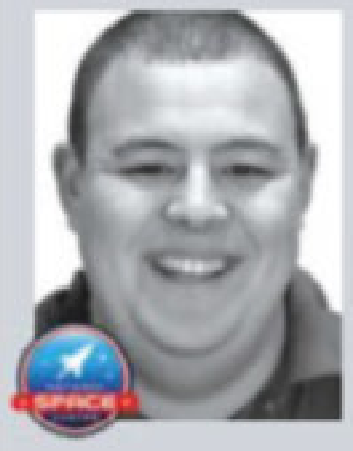
Zoe Baily



National Space Centre

■ Zoe holds a master's degree in interdisciplinary science and loves the topic of space as it brings together many different scientific disciplines.

Josh Barker



Education team presenter

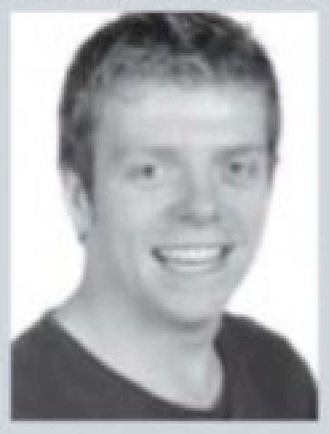
■ Having achieved a master's in physics and astrophysics, Josh continues to pursue his interest in space at the National Space Centre.

Gemma Lavender

Staff writer

■ Gemma has been elected as a fellow of the Royal Astronomical Society and recently joined the **All About Space** team on a permanent basis.

Jonathan O'Callaghan



Features Editor

■ Jonathan read Physics and Astrophysics at university and worked for our sister publication **How It Works** before joining **All About Space** magazine on issue 1.

The Voyager missions, like all unmanned craft, follow a curved path in space

SPACE EXPLORATION

Do unmanned spacecraft travel in straight lines?

Tom Wilson

All spacecraft that we have sent out of Earth's atmosphere travel along a curved path, rather than a straight line, through space. What essentially happens is that an initial rocket boost puts the craft in an elliptical orbit around the Sun that will enable it to intersect with the planet that a given space agency - such as NASA or ESA - has chosen as its target.

Consider Voyager 2, the spacecraft that visited all four of the gas giants, which was put into an orbit that enabled it to intersect with Jupiter. Using Jupiter's gravity, Voyager 2 was then able to slingshot into an orbit that intersected the ringed planet, Saturn. Further still, it was thrown out to Uranus and Neptune before moving into a slightly curved - and almost straight - orbit out of the Solar System. As far as we know, the craft is still following this path. **JOC**

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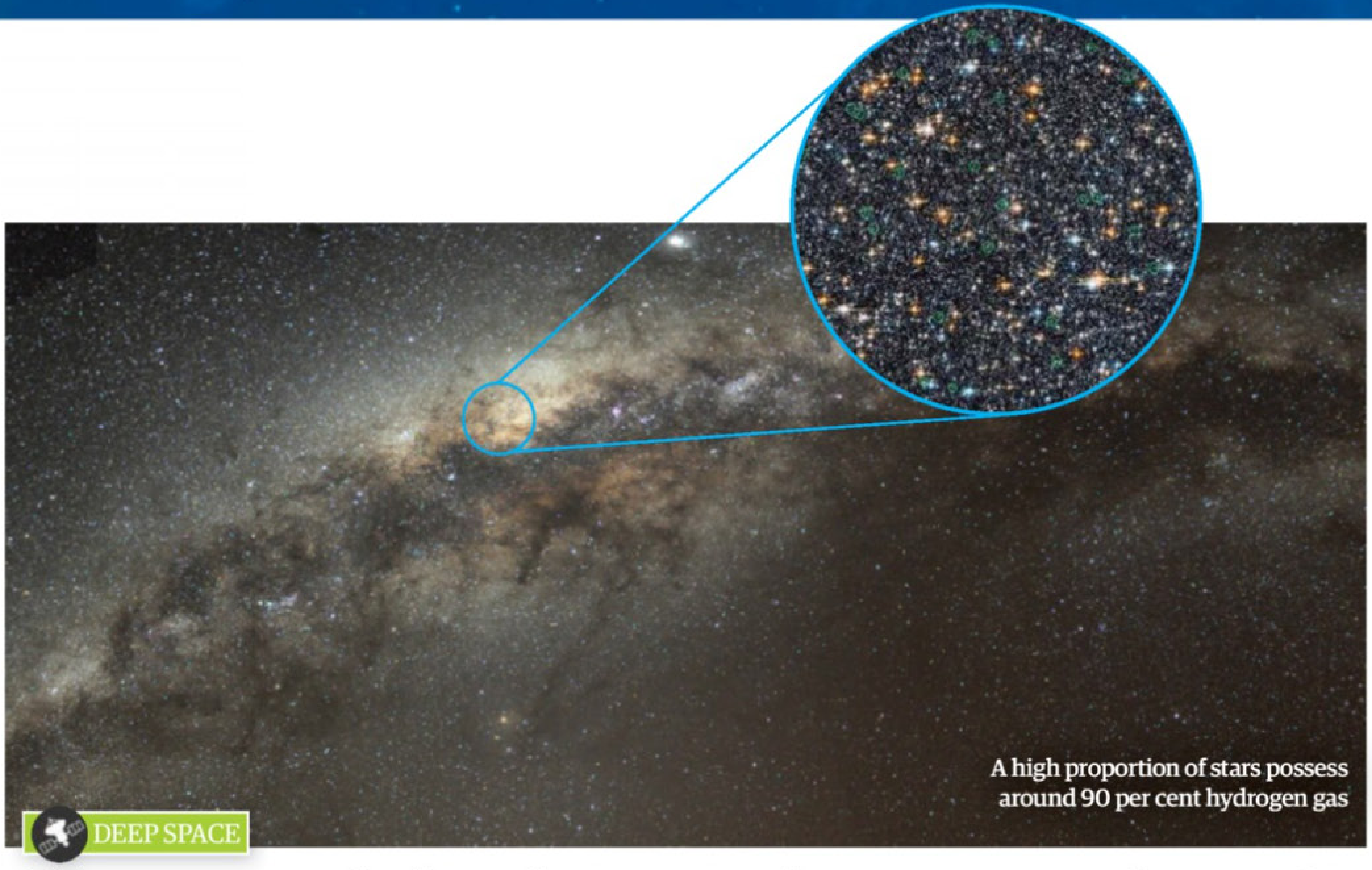


A high proportion of stars possess around 90 per cent hydrogen gas

DEEP SPACE

How much hydrogen does a star have?

Ben Sulivan

Many stars are made of about 90 per cent hydrogen, with most of the remainder being helium and a very small fraction of heavier elements.

Stars form from the sudden collapse of clouds of interstellar matter and during its lifetime a star burns its hydrogen to form helium. In fact, in order for a star to form, it must be able to start the process of burning hydrogen. Whether or not a star can begin this process is dependant on the collapsing interstellar cloud's mass.

The original conditions of the interstellar cloud can determine a star's type, how bright it is and how long it's likely to last. Stellar composition can vary - newer stars are found to have a relatively higher percentage of heavier elements. However, for their birth they need conditions that enable them to burn their hydrogen. **ZB**

SOLAR SYSTEM

A comet's tail can extend nearly 600 million kilometres across space

How long is a comet's tail?

Adam Cooper

The length of a comet's tail can extend nearly 600 million kilometres (373 million miles) across space - that's nearly four times the distance between the Earth and the Sun.

Comet tails begin to form as these space snowballs approach the orbit of Jupiter. As the comet gets closer to the Sun it begins to feel our star's heat and as it warms the frozen material begins to sublimate. This is a process when solids transition to gases.

As the ice gradually sublimates, it's held around the cometary nucleus by gravity, which becomes something called a coma. This part of the comet is affected by the solar wind, which pushes the cloud of gases out and away from the Sun to form the long and iconic comet tail. **JB**

The Large and Small Magellanic Clouds only touch the horizon for a few minutes at the furthest northern latitude

ASTRONOMY

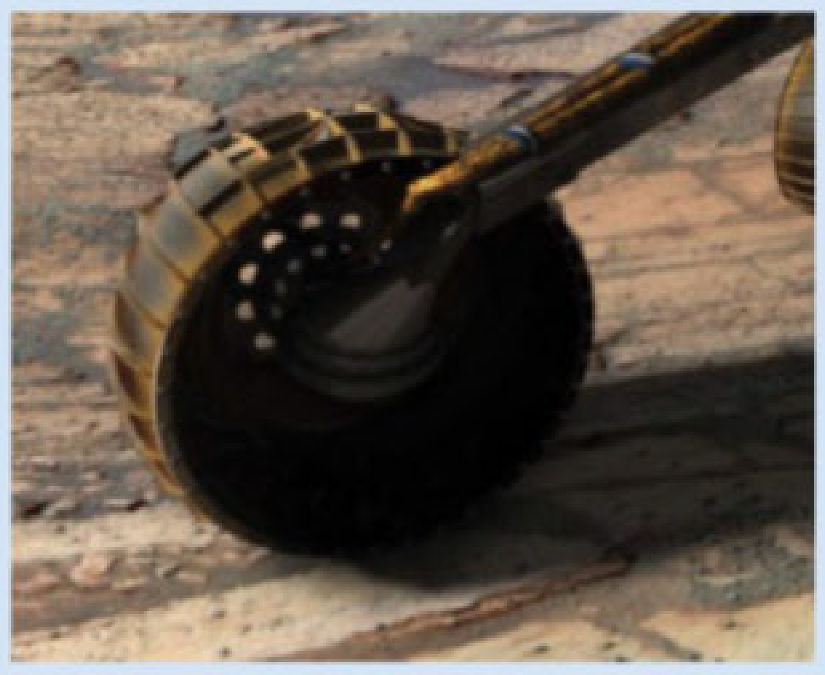
Can I see the Magellanic Clouds from the Northern Hemisphere?

Lucy Bennett

The Magellanic Clouds, comprising of both the Small and Large varieties, are irregular galaxies that are most easily viewed from the Southern Hemisphere of Earth.

The LMC and SMC are at a declination of around -70 degrees but the farthest northern latitude from which you would be able to see them would be at around 20 degrees. However, since the stars and the many objects that dot the night sky move in circles around a celestial pole due to Earth's rotation, a night-sky object at -70 degrees would only just touch the horizon for a few minutes before setting again.

If you stood on the Earth's equator, the Magellanic Clouds might be visible for a few hours, but only during certain times. **GL**



The wheels of sister rover Opportunity seem to be faring much better than those of Curiosity

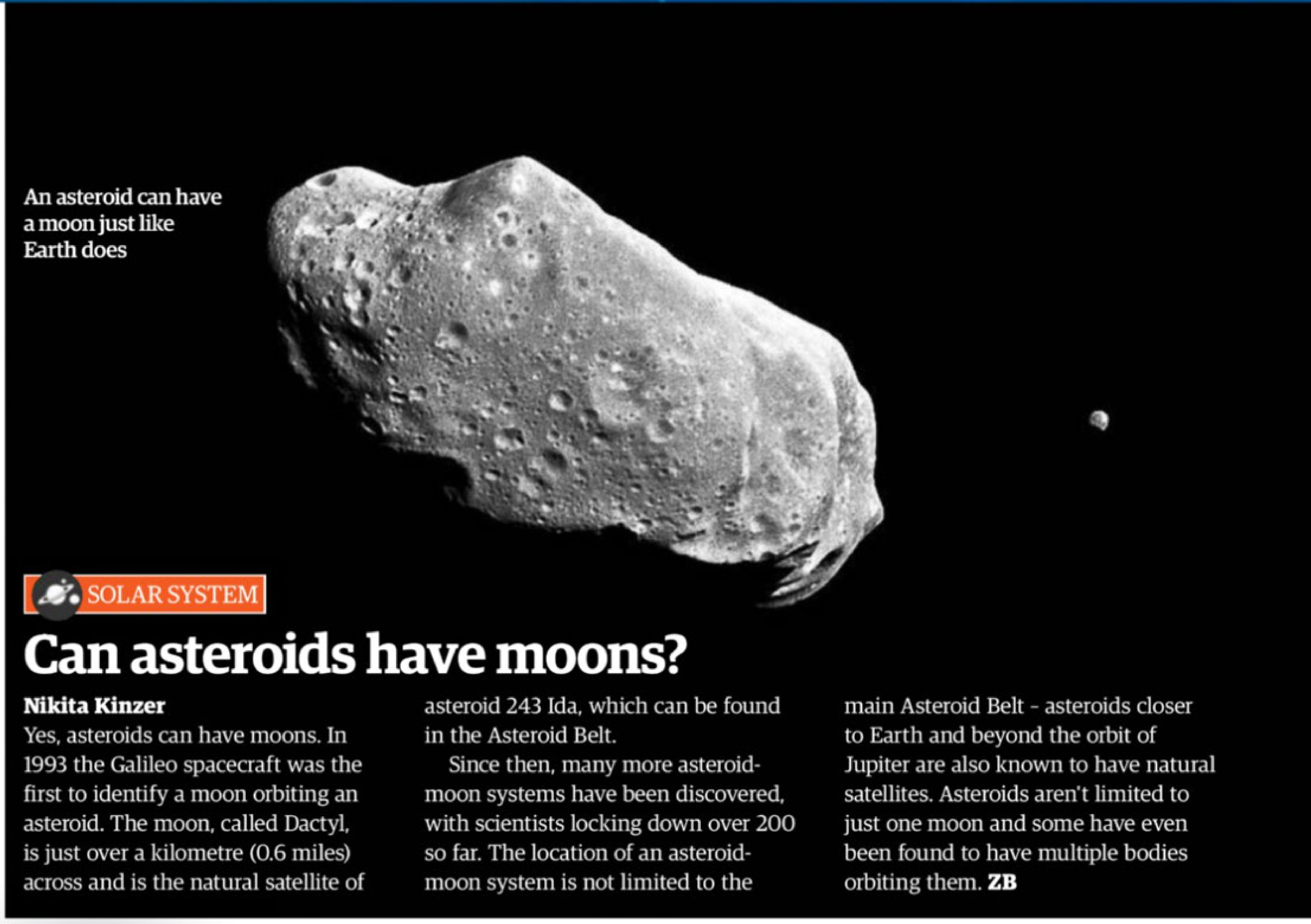
SPACE EXPLORATION

Why are Curiosity's wheels struggling?

Katy Baldwin

Followers of the Mars rover will be aware that recently Curiosity has developed some problems with wear on its wheels. This problem is a result of the harsh terrain that the rover is exploring. Curiosity has been sent to explore the rocky mountainous region at the base of Mount Sharp and the base of this mountain has presented much more of a challenge than experienced by other rovers. For the majority of their missions, Spirit and Opportunity explored fairly flat plains.

This harsh terrain, compounded with the weight of Curiosity, adds additional stresses. In order to limit the damage, the rover is currently in a period of driving in reverse so that its rear wheels take the brunt of the strain for a while. **JB**



An asteroid can have a moon just like Earth does

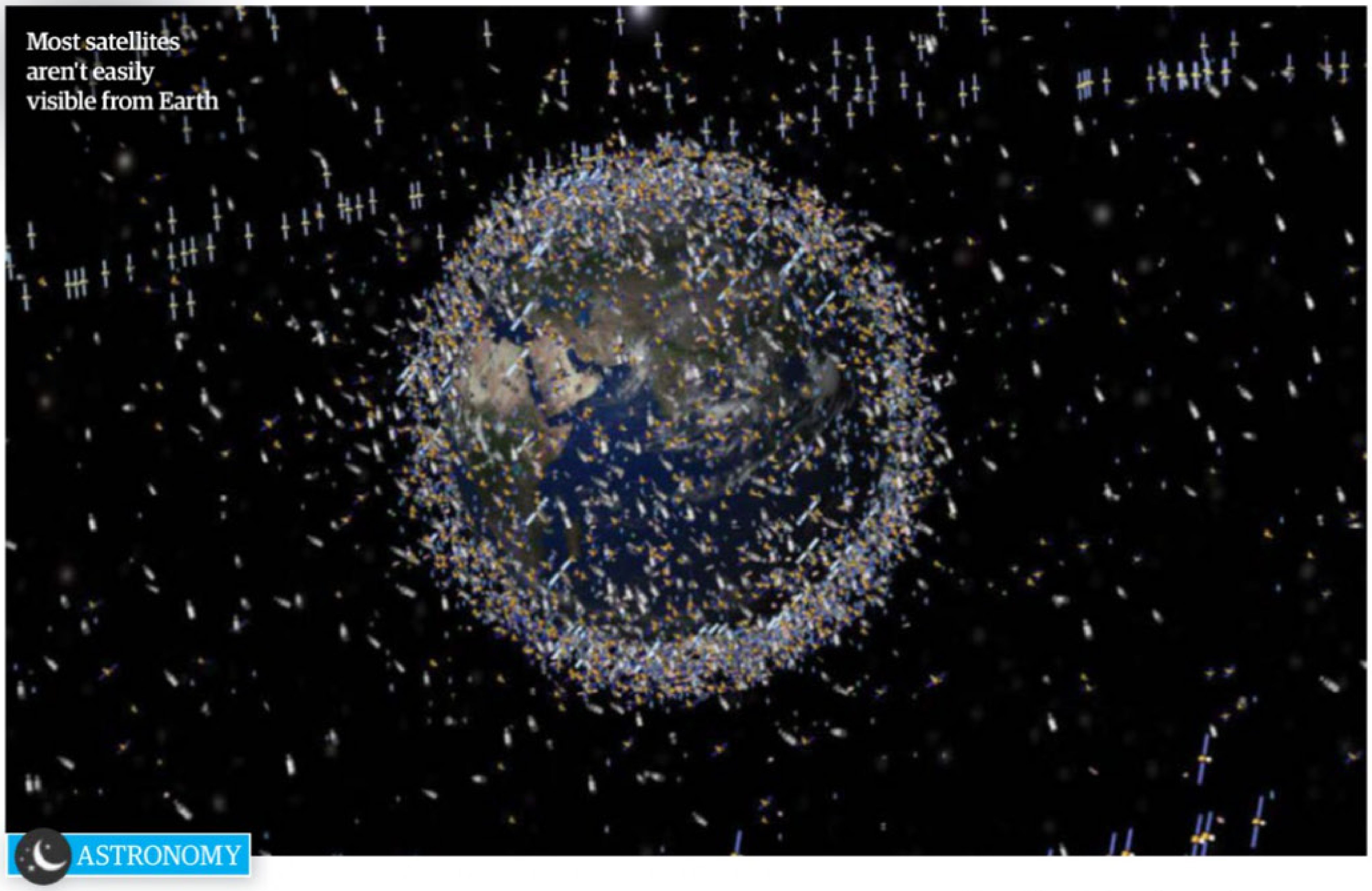
SOLAR SYSTEM

Can asteroids have moons?

Nikita Kinzer

Yes, asteroids can have moons. In 1993 the Galileo spacecraft was the first to identify a moon orbiting an asteroid. The moon, called Dactyl, is just over a kilometre (0.6 miles) across and is the natural satellite of asteroid 243 Ida, which can be found in the Asteroid Belt.

Since then, many more asteroid-moon systems have been discovered, with scientists locking down over 200 so far. The location of an asteroid-moon system is not limited to the main Asteroid Belt - asteroids closer to Earth and beyond the orbit of Jupiter are also known to have natural satellites. Asteroids aren't limited to just one moon and some have even been found to have multiple bodies orbiting them. **ZB**



Most satellites aren't easily visible from Earth

ASTRONOMY

Why can't we see all of the satellites in Earth's orbit?

Rachel Newman

Observing a satellite is actually incredibly tricky, with only a few being viewable from the ground. Satellites orbit the Earth roughly between 300 to 36,000 kilometres (186 to 22,369 miles) above its surface. This distance is what makes it so hard to see these objects as they travel overhead. When we look for satellites it's the equivalent of standing in London and trying to spot a car in Paris. Without specialist equipment it's virtually impossible to spot most satellites.

The most famous visible satellite is the International Space Station when it's in low orbit. Not only is it larger than most satellites, its large solar panel array makes it quite reflective and easily visible. **JB**

Questions to... @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com

DEEP SPACE

What is a magnetar?

James Bannister

A magnetar is a type of neutron star, a strange object with an incredibly powerful magnetic field that powers the emission of highly energetic X-rays and gamma rays. Neutron stars are formed when the largest stars in the universe reach the end of their lives. When these stars run out of fuel, their core collapses, causing outer layers to come crashing in towards the centre.

As stars are so large, the crushing forces created can be phenomenal. These pressures can squash the core of the star together and because of this, a neutron star – and so a magnetar – is made of some of the densest material in the known universe. In fact, the material is so dense that one teaspoon of it contains the same amount of mass as 900 Egyptian pyramids. **JB**

Discoveries made in 2008 by ESO's Very Large Telescope (VLT) suggest that many neutron stars could spend a period of time as a magnetar

SPACE EXPLORATION

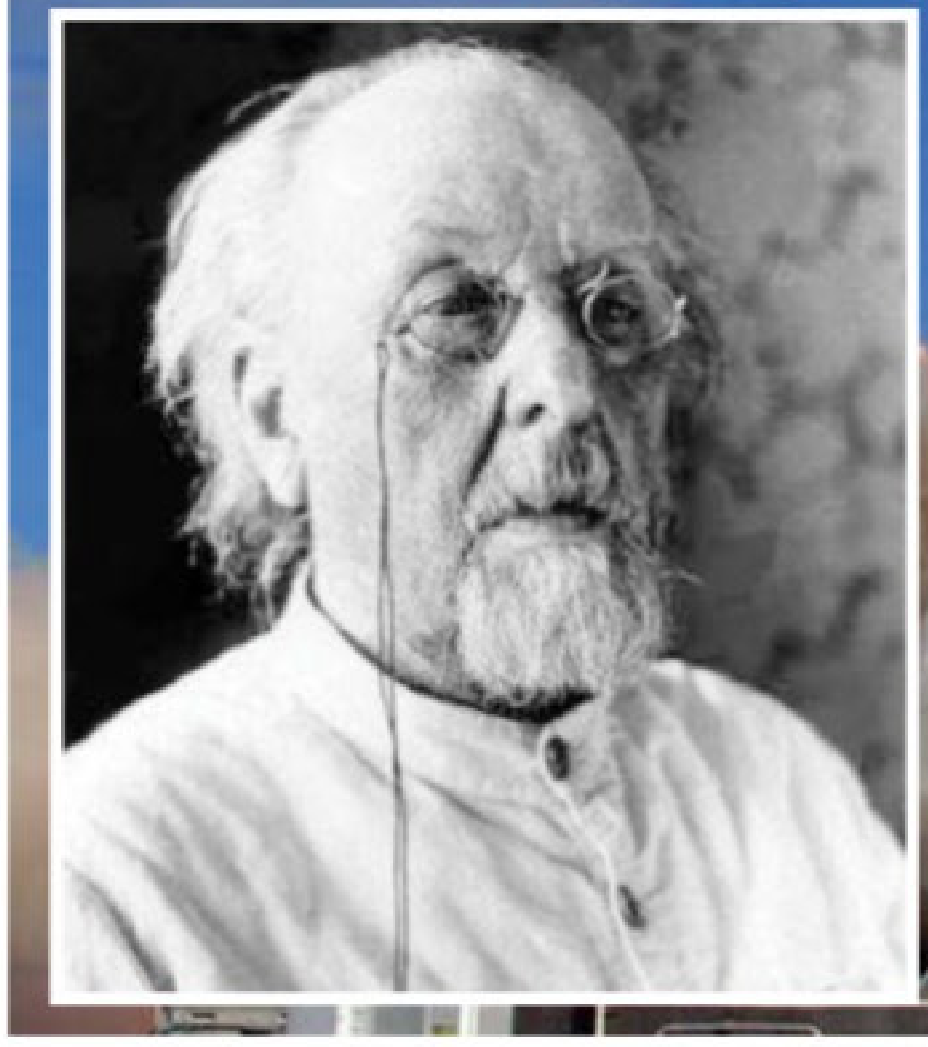
Who was Tsiolkovsky?

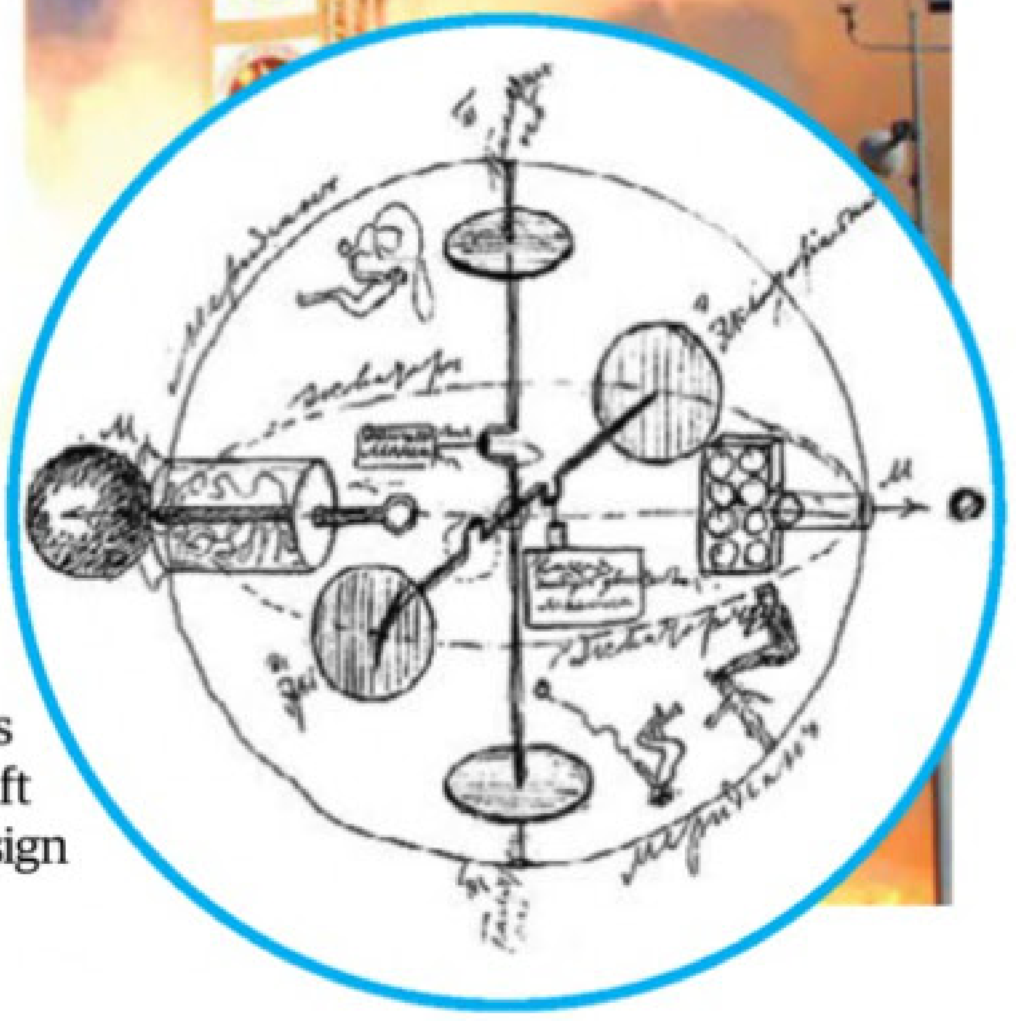
Jamie Greene

Konstantin Eduardovich Tsiolkovsky was a Russian teacher and scientist who is credited with being one of the founding fathers of rocketry.

He was born in a small village south-east of Moscow in 1857 and grew to be an avid learner, self-educating himself from books. Although picking up a career as a teacher, Tsiolkovsky also spent his time studying and writing. He was fascinated with the idea of exploring space and his writings are considered the first scientifically sound proposals of the use of rockets for such an endeavour. His scientific publications were theoretical, using mathematics and physics to establish basic rocket dynamics. Introducing concepts such as liquid propellants and multistage rockets, his visionary work is still the basis of modern aerospace engineering. **JB**

Konstantin Tsiolkovsky was the father of astronautics, as well as rocket dynamics





This (left) is Tsiolkovsky's first draft for a spaceship design

Quick-fire questions

@spaceanswers

What would happen if you poured water when in space?

Outside of a spacecraft, water poured into space would rapidly vaporise or boil away. Since there is no air in space, there's also no air pressure, meaning that the liquid can boil away at extremely low temperatures.

What's the difference between a meteorite and meteoroid?

A meteoroid is the debris that burns up when it enters Earth's atmosphere and is frequently only a matter of millimetres in size. If it doesn't burn up, it hits the Earth's surface as a meteorite.

Can artificial gravity be created in space?

By spinning your spacecraft or space station, it's possible for you to create artificial gravity in space. Spinning creates forces that act to pull objects outwards, simulating a force similar to gravity.

What is the hottest time of day?

Many think that it's noon, however that's when you have the most direct sunlight. It takes time for the atmosphere to warm, making some time in the afternoon the hottest period.

Can moons have moons?

In theory, it's possible for a moon to have a moon, existing in the region of space around a satellite as a sub-satellite. This region is called the Hill sphere.

Who named Pluto?

In 1930 Venetia Burney, who was 11 years old at the time, suggested the name Pluto for the ninth world from the Sun.

Where was the water in the Big Bang?

The Big Bang contained all the materials required to make water. These essential materials formed over billions of years to create today's water.

Quick-fire questions

@spaceanswers

What is found at the end of the universe?
There's nothing that we know to be the ultimate end of the universe, but there are three possibilities: the Big Crunch, Big Rip or Big Freeze.

Why are craters round?
The energy involved in an impact is so great that when an impactor hits the ground, it explodes like a bomb. Explosions are fairly symmetric, so craters from impacts are usually circular.

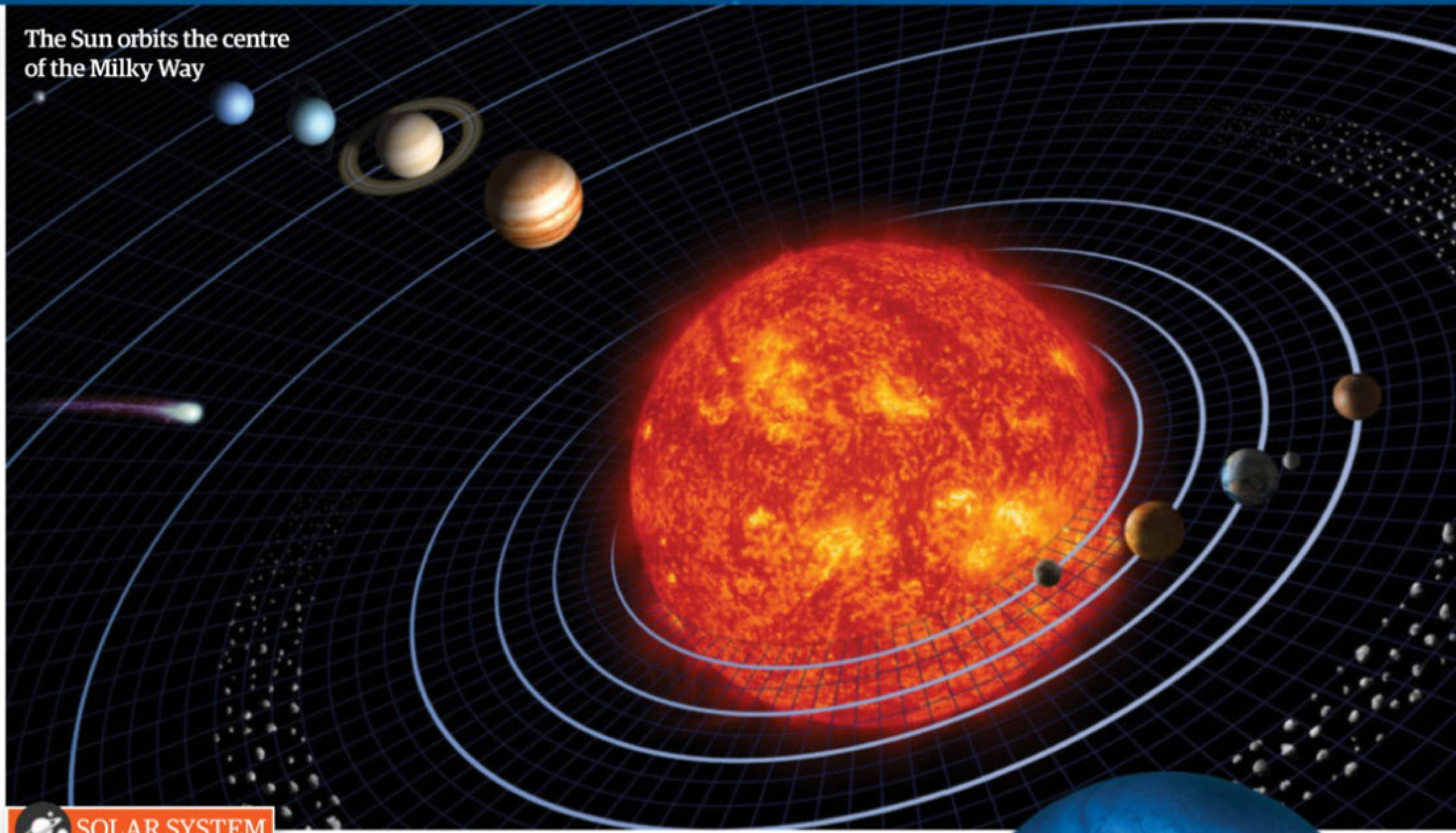
Have we ever seen a star switch on?
Astronomers have never seen a star turning on like a switch has been flicked. That being said, we have seen stars at every stage of their evolution.

What is a graviton?
A graviton is a hypothetical particle with no charge and no mass. It carries what we understand to be the gravitational force in the universe.

How do we know the density of some exoplanets?
When an exoplanet moves across its star in transit, we are able to work out its mass based on its orbit. Combined with getting an estimate of a planet's size, we can also get the density.

Are there solar tides?
Yes, the Earth has a small tidal bulge due to the Sun's gravitational tug. However, since the Moon is much closer to us, we feel much stronger lunar tides.

How do astronauts communicate in space?
Electromagnetic radiation can travel through space. Radio belongs to this spectrum and can be used for devices in astronauts' helmets so they can converse.


The Sun orbits the centre of the Milky Way

SOLAR SYSTEM

Does the Sun move in space?

Sonia Crabtree

Clearly we know that the planets, asteroids and comets of our Solar System revolve around the Sun. However, our star is also moving itself - orbiting around the centre of our galaxy, the Milky Way.

At a distance of around 25-30 thousand light years from the galactic centre, the Sun - as well as everything that orbits it - is travelling at an average speed of around 828,000 kilometres (514,495 miles) per hour. This means that it would take our Sun about 230 million years to complete one lap around the Milky Way.

Our star also rotates with different layers of the gases that its comprised of, moving at various speeds in what is known as differential rotation. **GL**

ASTRONOMY

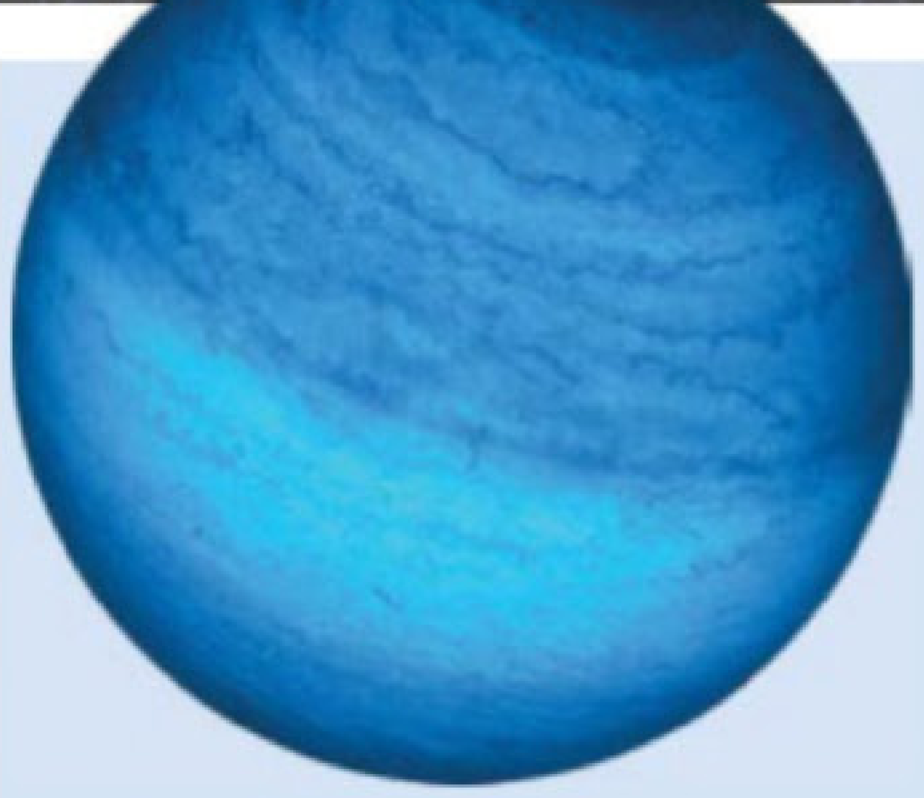
Can I see a quasar with my telescope?

Luke Harris

With a medium-sized telescope, you can see a quasar; an overactive galactic centre that spits out high-energy radiation. However, you won't see one in the way that artist's impressions and other images suggest and it will look just like a star.

Perhaps one of the most famous and earliest quasars to be identified is 3C 273, located in the constellation Virgo that rests around 2.5 billion light years away. At over a trillion times brighter than the Sun, its distance means it only shines at a magnitude of +12.9, so you'll require at least an eight-inch telescope to see it. **GL**

A medium-sized telescope will enable you to see a quasar


Rogue planets are worlds that don't orbit a star

DEEP SPACE

How are rogue planets made?

Jonathan Richardson

Rogue planets - worlds that don't orbit a star but instead move around the galaxy directly - may have formed in a planetary system similar to how the planets in our Solar System did before being cast out by their parent system.

Alternatively they may never have been bound to a parent star or brown dwarf in the first place. Worlds taking on a mass typical of a planet, that have enough gravity to take on a rounded appearance but not so much that they can sustain fusion in their core like a star would, might have formed in a similar way to stars. This caused astronomers to label them sub-brown dwarfs, where they formed through the collapse of a gigantic gas cloud. **JOC**

The location of a galaxy's halo is hard to determine

DEEP SPACE

Where is the halo of a galaxy?

John Cope

Spiral galaxies, similar to the Milky Way, are usually made of three basic components that are visible to us; the disc with its spiral arms, a nucleus or central bulge and the halo that encompasses them.

A galaxy's halo appears to extend beyond the galaxy's disk but due to no real defined edges, it's difficult to measure this part of the galaxy precisely. The halo contains little gas, dust or star formation. Star clusters that reside here are usually globular clusters, containing very old, metal stars. We can date these star clusters, and so the galaxy, with some reaching ages of over 12 billion years old. It's found that stars of the halo are in more elliptical and randomly orientated orbits than stars that you'll find in a galaxy's disc **GL**

ASTRONOMY

How many galaxies can we see with a telescope?

John Watson

The answer to this question varies from 'very few' to 'billions' depending on your telescope.

Astronomer Galileo Galilei first discovered that pointing a telescope at the night sky would reveal hidden stars. Of course, these weren't hidden, but just too faint to see with the naked eye.

With time we have endeavoured to build ever bigger telescopes as it was clearly understood that the larger a telescope's mirror, the fainter the object that could be detected. This continued until we started to use other regions of the electromagnetic spectrum. Harnessing our understanding of light has enabled us to continue probing our universe, discovering more and more objects within it. **SA**

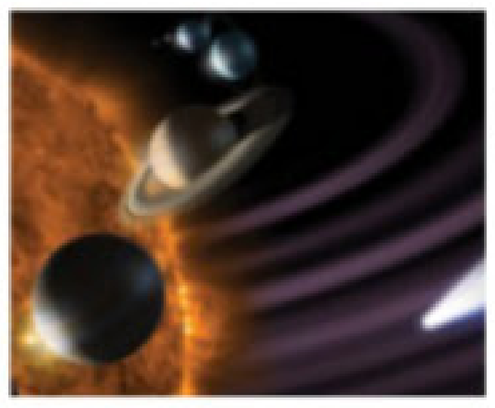
How many galaxies you can see depends on the telescope

© NASA; ESO; ESA

Next Issue

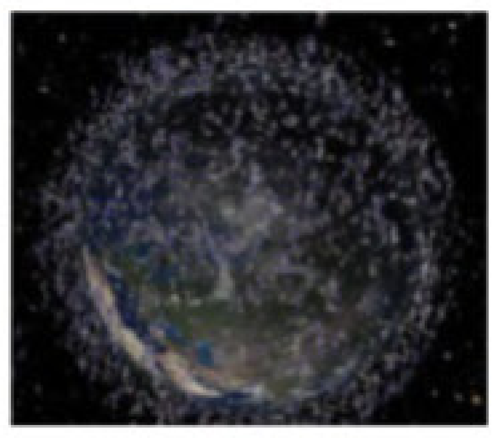
RETURN TO THE MOON

Discover lunar landers, Moon colonies and a far-side telescope



HIDDEN PLANETS

Are there really worlds we're yet to discover in our own Solar System?



DEADLY SPACE JUNK

The missions to clean up the critical mess in Earth's orbit

ALL ABOUT KEPLER 64

Read about the quadruple-star system and its giant molten exoplanet

+

THE ROBOT APE PILOT
STARGAZING PARTY GUIDE
SMALLEST STARS IN SPACE
THE MICROBOT EXPLORER
BILLION STAR SURVEYOR
SUPERSONIC WIND TUNNEL

In orbit **1 May 2014**

STARGAZER

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How to find the thrilling features of the Red Planet

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93 **Astronomy kit reviews**
The latest essential astronomy gear and telescopes reviewed

Backyard astronomy on a budget

All About Space brings you all of the fun of astronomy without breaking the bank

There's no doubt about it, when it comes to first choosing and purchasing equipment to observe the night sky, there's a lot to take in. Which telescope should you get? Which magnification is best for a first pair of binoculars? Do you need to buy extra eyepieces?

These are possibly just some of the questions that you may have found yourself puzzling over when it's come to choosing astronomy kit. It may have been that the daunting task of selecting a telescope or pair of binoculars has put you off pursuing a hobby in astronomy. Maybe you have bought a telescope that doesn't meet your requirements and is too complicated for you to use. If you took the plunge before you were ready, it's most likely left you feeling frustrated and disappointed, with nothing to show for your efforts other than a piece of equipment gathering some dust in a rarely visited corner of your home - not to mention a lower bank balance.

Blunders like this aside, it certainly is possible to take part in backyard astronomy without having to spend an incredible amount. The trick is to do your research, whether that involves reading up on your hobby in stargazing books, or getting some advice from a seasoned amateur astronomer at your local astronomical society before you make your first purchase. Additionally, it's also essential that you shop around to compare prices, making sure that there's a satisfactory trade-off between how much you can afford and what your potential piece of equipment can actually offer.

Last, you should always think ahead - will your equipment still be usable a year into your backyard astronomy hobby?

Where first-time astronomers often get lost is not being able to figure out what they should be looking for in an ideal piece of equipment, by thinking that bigger and more expensive is better. This isn't always the case - it's always down to the individual and a telescope that enables you to do what you want - and nothing else - at a reasonable cost is definitely a step in the right direction when it comes to figuring out a budget.

Still at a loss? Don't worry. This guide will ensure you get what you want for many worthwhile evenings under the stars, with minimal fuss and without breaking the bank. ●

Find your way around the night sky

PHILIP'S
PLANISPHERE
SHOWS THE POSITIONS OF THE STARS AND CONSTELLATIONS FOR ANY HOUR IN THE YEAR

Learning your way around the night sky is essential before buying any equipment

Getting a good idea of the constellations and identifying naked-eye objects such as planets, star clusters and prominent stars will help you find objects with the equipment that you might be intending to buy later on. These objects can act as signposts in the night sky, pinpointing hidden treasures that you could have the chance of meeting further into your hobby.

If you're unfamiliar with what's out there and unsure of the prime targets during the winter, summer, autumn and spring skies, then you should certainly invest in a planisphere or a guide to the night sky. This won't just show you where everything is, but which objects you can observe throughout the calendar year.

Many of these guides are less than £10 (approx. $16), which means that you wouldn't have to spend too much if you were to change your hobby.

Your planisphere will be a guide that you can use over and over again. Remember, there's no time limit to how long you should spend partaking in naked-eye astronomy, so take your time in getting acquainted with the heavens.

Philip's Planisphere (Classic 11.5")
Cost: £9.99 / $11.90
From: www.amazon.co.uk / www.amazon.com

Nightscenes 2014: A Monthly Guide to the Astronomical Events for the Year
Author: Paul Money
Cost: £6 / $N/A
From: www.astrospace.co.uk

Philip's Guide to The Night Sky
Author: Sir Patrick Moore
Cost: £5.99 / $3.99
From: www.amazon.co.uk / www.amazon.com

Your first pair of binoculars

Without a shadow of a doubt, a pair of binoculars is the way to go when it comes to using your first piece of equipment. Not only do they promote minimum fuss and can be turned to any object with ease – unlike a telescope which will need polar alignment – but the pair that you're likely to be using don't require any setting up. You'll also have much more freedom of movement, magnifying objects without spending a great deal of money.

If your budget is less than £100, it may be worth investing in a good pair of binoculars rather than a low-quality telescope. Remember that your binoculars can double-up as sight-seeing aids on holiday as well as nature-watching, providing a multitude of purposes in one hit.

You'll find that binoculars are usually marked with figures such as 8x40, 7x50 or 10x50 – here the first figure is the magnification while the second is the aperture of the lenses built into the binoculars, in millimetres. For casual observing your best bet is to go for 7x50 or 10x50 binoculars, since they are both equally useful. Remember that the greater the aperture, the heavier the binoculars, so if you find that 50mm is too heavy for you to hold steady, opt for 40mm or even 30mm models. Alternatively, when it comes to the compromise between weight and power, many go for 8x32 or 8x42 binoculars.

The heavier the devices get, the more likely you'll need a tripod – it'll be difficult to observe anything when your arms are shaking under weight, so choose wisely.

Meade 10x50 Binoculars
Cost: £38.99 / $N/A
From: www.harrisontelescopes.co.uk

Celestron Nature 8x42 Porro Binoculars
Cost: £74.99 / $139.95
From: www.harrisontelescopes.co.uk / www.amazon.com

Ostara Elinor 10x50 Binoculars
Cost: £199.99 / $N/A
From: www.opticalhardware.co.uk

Go for...

- ✓ Binoculars with coloured coatings on their optics – these will improve image brightness
- ✓ Binoculars with a good balance between light-gathering capacity, magnification, weight and cost
- ✓ Porro or BAK-4 prisms that offer 8x magnification and reasonably large object lenses of 42mm plus

Avoid...

- ✗ Magnifications greater than 12x – unless you have a particular need for specialist binoculars
- ✗ Binoculars that are too heavy for you to hold – they'll be difficult to keep steady without a tripod
- ✗ Zoom binoculars – they have narrow fields of view and relatively poor optics

> "Your binoculars can double-up as sight-seeing aids"

Your first telescope

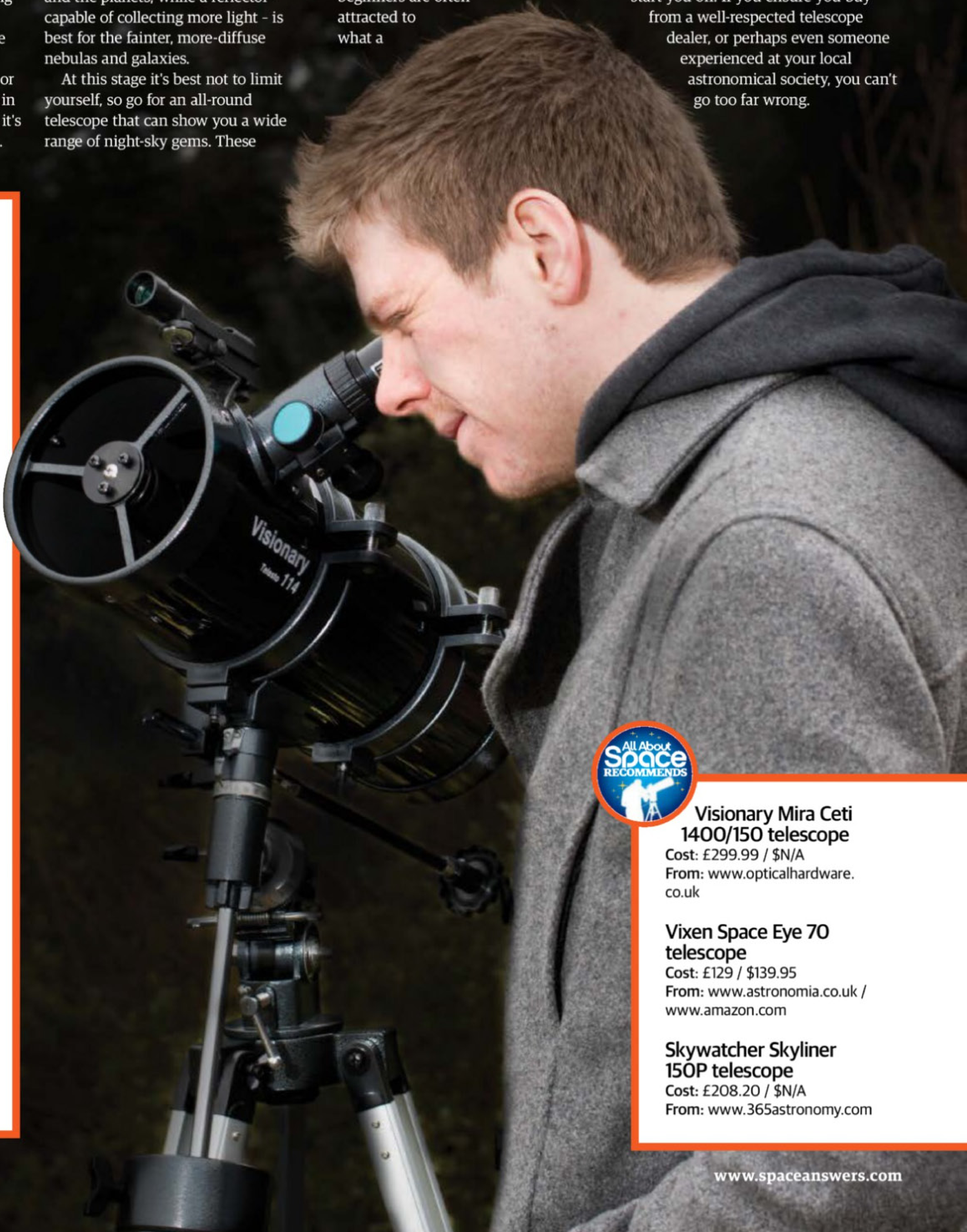
At this stage, you might be looking to upgrade your binoculars to look deeper into the night sky. Before you purchase a telescope, however, there are a few things you should consider.

First, think about whether you're familiar enough with the night sky and second ensure that buying a telescope will improve your observing experience. There's little point in spending more money on a telescope when it doesn't give much more magnification than your binoculars, or if it's likely to end up gathering dust in your home. Before buying anything, it's always best to consider these factors.

Choosing your telescope can be a challenge when you don't know what you're looking for, so once again it's important to know how much you're willing to spend and what capabilities you want your telescope to have. It's said that refractors are best for checking out the craters on the Moon and the planets, while a reflector – capable of collecting more light – is best for the fainter, more-diffuse nebulas and galaxies.

At this stage it's best not to limit yourself, so go for an all-round telescope that can show you a wide range of night-sky gems. These are often referred to as Newtonian or the hybrids Schmidt-Cassegrain, Maksutov-Cassegrain or catadioptric telescopes. It may be tempting to opt for a GoTo telescope, which can just point you to any object you wish, however, these can be difficult and time-consuming to set up. Many beginners are often attracted to what a Dobsonian telescope (a type of Newtonian telescope) has to offer in the trade-off between price and overall performance.

A good sturdy Newtonian telescope should cost you around £200 while a good refractor could be as little as £300 with a tripod and eyepieces to start you off. If you ensure you buy from a well-respected telescope dealer, or perhaps even someone experienced at your local astronomical society, you can't go too far wrong.



Go for...

- ✓ Telescopes that come as a complete package; most come with a tripod, finderscope and an eyepiece or two
- ✓ An instrument that meets your needs – don't buy an expensive telescope blindly without doing any research
- ✓ The higher the aperture, the better. The larger it is, the sharper and brighter your image
- ✓ Good focal length, depending on the objects you want to view. Get long focal lengths for high-power objects like the Moon and planets and shorter focal lengths for taking in larger areas of sky
- ✓ A steady, sturdy and smoothly working mount

Avoid...

- ✗ Cheap, poor-quality models that you can often find being sold in high-street stores or in mail-order catalogues
- ✗ Telescopes that are particularly difficult to set up
- ✗ Devices that offer fantastic magnification for very little cost – if it sounds too good to be true, then it most probably is
- ✗ Telescopes that are too heavy for you to carry
- ✗ Devices that come with eyepieces with barrels less than one-and-a-quarter inches
- ✗ A finderscope with a tube hardly thicker than your finger, or that gives a dim, fuzzy view

All About Space RECOMMENDS

Visionary Mira Ceti 1400/150 telescope

Cost: £299.99 / $N/A
From: www.opticalhardware.co.uk

Vixen Space Eye 70 telescope

Cost: £129 / $139.95
From: www.astronomia.co.uk / www.amazon.com

Skywatcher Skyliner 150P telescope

Cost: £208.20 / $N/A
From: www.365astronomy.com

Filters and eyepieces: get the most from your device

Hopefully by this stage you should have found a telescope that meets all your requirements and was bought within your budget. You're most likely impressed with the views that your instrument can bring into focus, but what if you could enhance or magnify them for even better sights? Extra eyepieces, lenses as well as filters can help you to do this.

Clearly eyepieces will work with your telescope's focal length and aperture to increase the magnification. Filters will give you a more-enhanced observing experience when it comes to looking at planetary features (such as the dust storms on Mars), the Moon and the faint dust and gas of even diffuse nebulas.

You are very likely to be supplied with higher and lower-power eyepieces with your telescope, but you may not be getting the most out of your device with these alone. This means it's worth considering if you can improve your instrument with a small amount of money before deciding to upgrade your telescope in the future.

The best types of eyepiece to go for, which give great viewing for little cost, are plossls. Remember that the larger the value on the eyepiece, the lower the magnification you'll get. It's also important to have a sense of how much magnification your telescope can handle, but eyepieces can be extremely useful in giving your telescope a much-needed power boost. Alternatively, you might decide to invest in a Barlow lens, which you can fit to your telescope, boosting the magnification of the eyepieces that you already have and saving money in the long run.

> "Filters will give you a more-enhanced observing experience"

All About Space RECOMMENDS

Orion HighLight Plossl
Cost: From £59 each / $N/A
From: www.scsastro.co.uk

Celestron Omni 2x Barlow
Cost: £59 / $47.95
From: www.astronomia.co.uk / www.amazon.com

Ostara Multiple 5-filter wheel
Cost: £90 / $N/A
From: www.opticalhardware.co.uk

Go for...

- ✓ Some alternative achromatic eyepieces for your device
- ✓ Ensure that your eyepieces come multi-coated
- ✓ Consider acquiring a Barlow lens to boost the power of eyepieces you already have
- ✓ The highest-quality filters that your budget will allow

Avoid...

- ✗ Wasting money on eyepieces that your telescope is going to struggle to handle
- ✗ Eyepieces with eye relief values that are too low for you
- ✗ Eyepieces that are too heavy for a delicately balanced telescope

Win!

A backyard astronomy bundle courtesy of Optical Hardware.

Worth over £600

Bundle includes:
Night Scenes 2014
Ostara Elinor 10x50 Binoculars
Visionary FirstView Telescope
Visionary Mira Ceti 1400/150 Telescope
Ostara Multiple 5-filter wheel

Turn to page 96 for more details on how to enter!

What's in the sky?

The nights are sparkling with deep-sky delights for observers as we look out into the depths of space

M3 globular star cluster

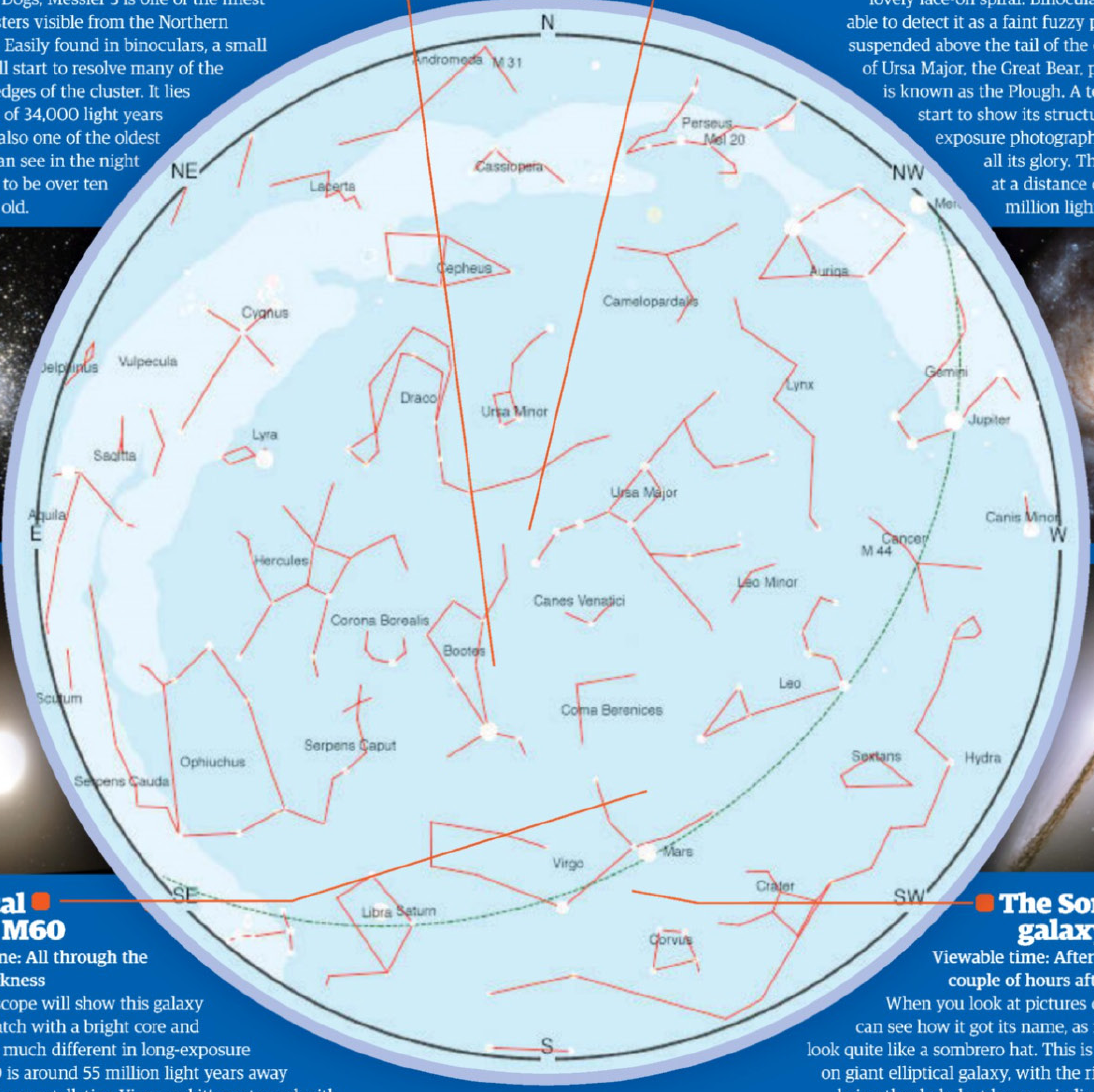
Viewable time: All through the hours of darkness

Lying in the constellation of Canes Venatici, the Hunting Dogs, Messier 3 is one of the finest globular clusters visible from the Northern Hemisphere. Easily found in binoculars, a small telescope will start to resolve many of the stars at the edges of the cluster. It lies at a distance of 34,000 light years away and is also one of the oldest objects we can see in the night sky, thought to be over ten billion years old.

Spiral galaxy M101

Viewable time: All through the hours of darkness

Known as the Pinwheel galaxy, M101 is a lovely face-on spiral. Binoculars should be able to detect it as a faint fuzzy patch of light suspended above the tail of the constellation of Ursa Major, the Great Bear, part of which is known as the Plough. A telescope will start to show its structure and long-exposure photography will reveal all its glory. The galaxy lies at a distance of around 20 million light years away.



Elliptical galaxy M60

Viewable time: All through the hours of darkness

A small telescope will show this galaxy as a fuzzy patch with a bright core and it won't look much different in long-exposure images. M60 is around 55 million light years away from us in the constellation Virgo and it's partnered with another galaxy, NGC 4647. Recent studies using the Hubble Space Telescope have shown that these two objects have started to interact gravitationally. The centre of this galaxy contains one of the largest black holes ever found.

The Sombrero galaxy M104

Viewable time: After dark until a couple of hours after midnight

When you look at pictures of M104, you can see how it got its name, as it really does look quite like a sombrero hat. This is a near-edge-on giant elliptical galaxy, with the rim of the hat being the dark dust lane encircling the galaxy. This is detectable in amateur telescopes but shows up better in long-exposure images. The galaxy lies around 30 million light years from us on the border of the constellations Virgo and Corvus.

Northern Hemisphere

The Butterfly cluster M6

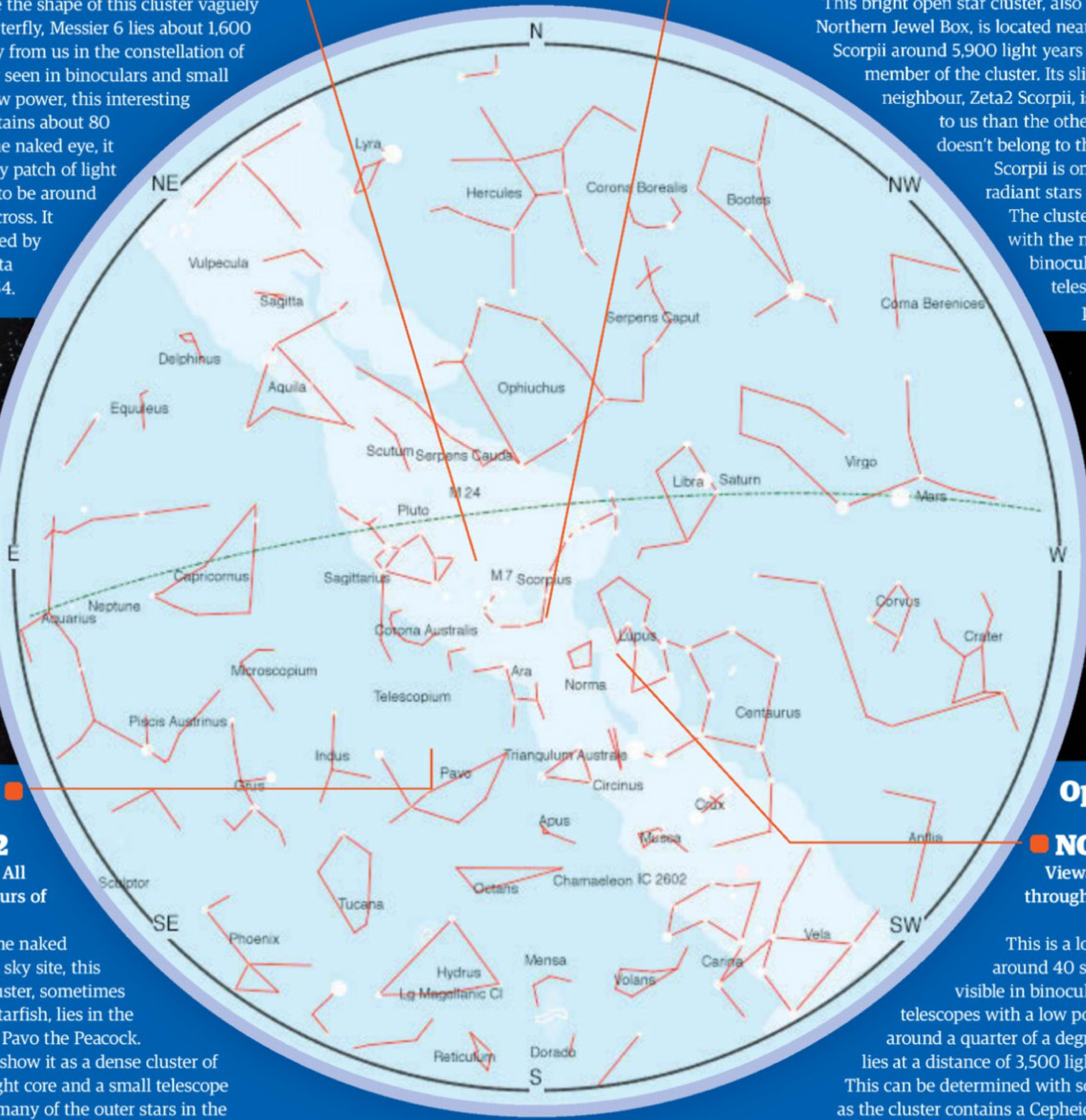
Viewable time: All through the hours of darkness

Named because the shape of this cluster vaguely resembles a butterfly, Messier 6 lies about 1,600 light years away from us in the constellation of Scorpius. Easily seen in binoculars and small telescopes at low power, this interesting star cluster contains about 80 members. To the naked eye, it looks like a hazy patch of light and is thought to be around 12 light years across. It was first recorded by Giovanni Battista Hodierna in 1654.

Open star cluster NGC 6231

Viewable time: All through the hours of darkness

This bright open star cluster, also known as the Northern Jewel Box, is located near the star Zeta Scorpii around 5,900 light years away and is a member of the cluster. Its slightly brighter neighbour, Zeta2 Scorpii, is much closer to us than the other stars and so doesn't belong to the group. Zeta Scorpii is one of the most radiant stars in our galaxy. The cluster can be seen with the naked eye, but binoculars and small telescopes show it perfectly well.



Southern Hemisphere

Globular cluster NGC 6752

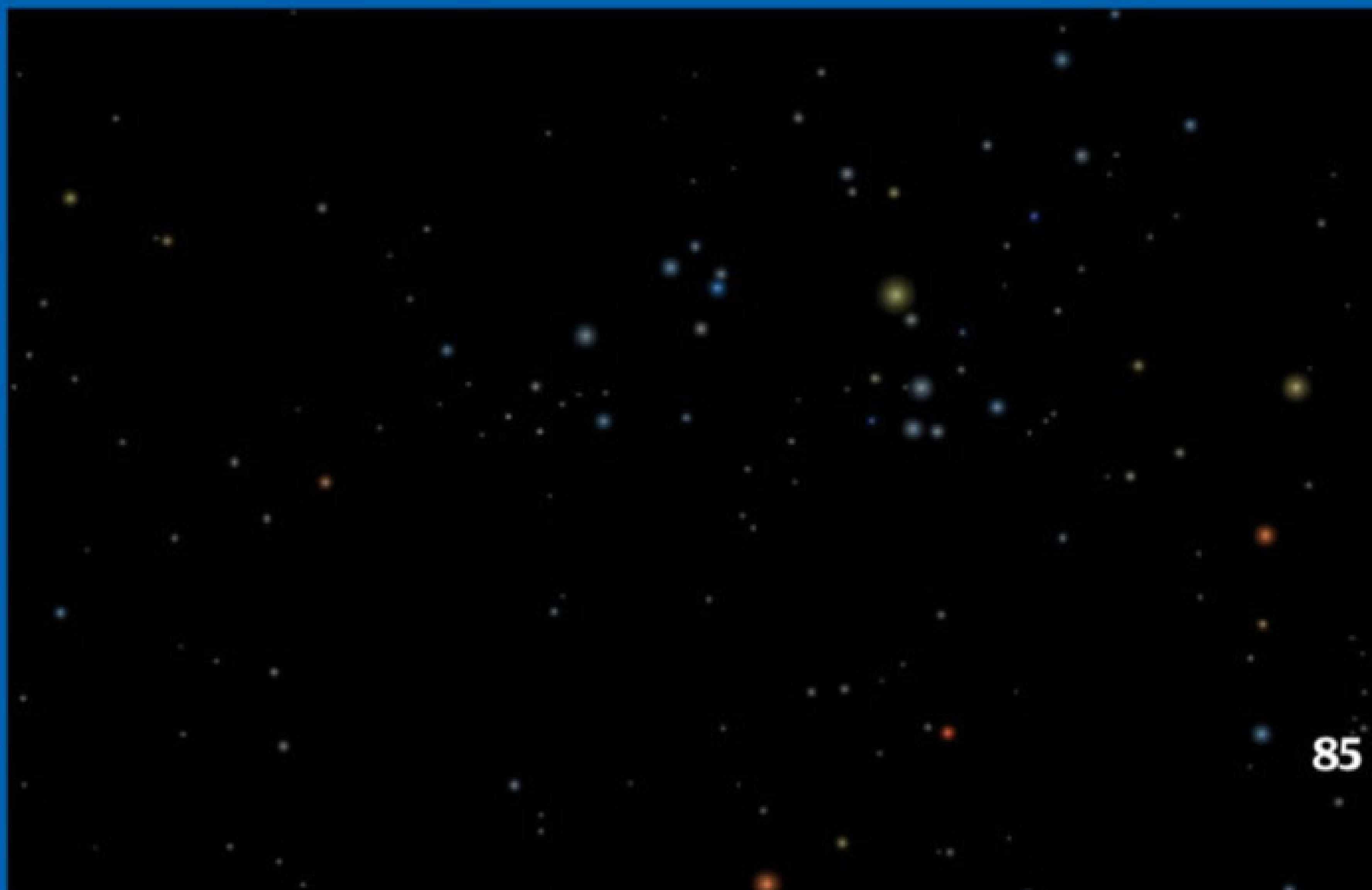
Viewable time: All through the hours of darkness

Just visible to the naked eye from a dark sky site, this globular star cluster, sometimes known as the Starfish, lies in the constellation of Pavo the Peacock. Binoculars will show it as a dense cluster of stars with a bright core and a small telescope should resolve many of the outer stars in the group. It's thought to be around 13,000 light years away from us and estimated at nearly 12 billion years old.

Open star cluster NGC 6087

Viewable time: All through the hours of darkness

This is a loose cluster of around 40 stars. Perfectly visible in binoculars and small telescopes with a low power, it covers around a quarter of a degree of sky and lies at a distance of 3,500 light years away. This can be determined with some accuracy, as the cluster contains a Cepheid variable star – a type which is used as a standard candle for distance measurements in deep space. It can be found in the constellation of Norma.



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Observer's guide to Mars

Reaching opposition in early April before making its close approach to Earth, the Red Planet will offer the perfect opportunity to observe its features

By the time you pick up your copy of **All About Space** the Red Planet will already be in the night sky, heading for or already reaching opposition in the constellation Virgo on 8 April. Opposition is the point in the sky where the planet is at its brightest and is at its best for viewing. As well as it being at the optimum position in the sky for observing, Mars will get quite close to Earth on 14 April at a distance of 92.4 million kilometres (57.4 million miles). It will be offering its northern-most hemisphere and interesting features as relatively easy pickings for moderate telescopes and larger.

When it comes to looking for the Solar System's planets in Earth's skies, Mars is perhaps the most distinctive. Yet, while we refer to it as the Red Planet, to the naked eye Mars appears to flit through pale orange-yellow to orange-red hues, depending on its distance from Earth. As the Red Planet moves in closer to us, it will get redder and hit a magnitude of around -1.5, presenting a 15.2 arc second disk that offers roughly equal viewing opportunities for observers in both hemispheres.

Currently it's northern summer on Mars and this brings about the onset of swirling dust storms that can sometimes grow so big they obscure the planet's surface completely. They tend to be most frequent around the Summer Solstice and when blowing across Mars they appear bright orange and featureless. High-altitude clouds may also be on the increase during the Martian summertime.

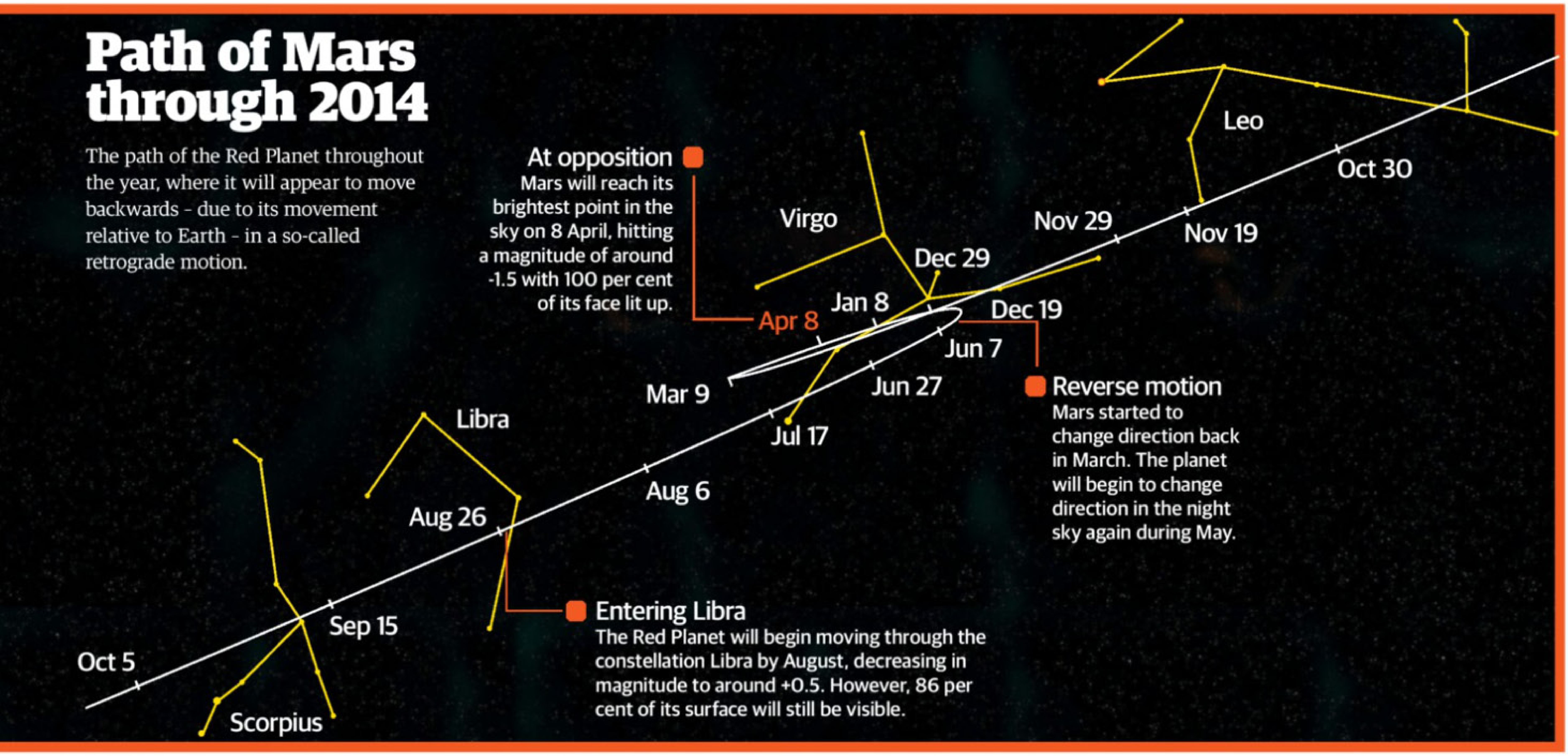
When the planet isn't swathed in high volumes of Martian dust, the features that Mars has to offer are rewarding, but spotting them requires patience. You will also need eyes well-adapted to the dark, as well as skies devoid of light pollution to pick out the fainter features, even with optical aid. We recommend at least a four- to six-inch aperture with added magnification of 200x or more, where Mars will fill your field of view.

You can make picking out the Red Planet's lesser dominating dust storms, darker regions and volcanic stretches easier with the help of filters – you can see these highlighted here. Dark-yellow or red filters will help you to pick out any contrasting darker features, while a red or blue filter will reveal dust storms and Martian clouds, respectively.

One other thing to be aware of when observing the Red Planet is the speed of its rotation, which is 40 minutes longer than the length of Earth's day. This means that at the same time each night on Earth, Mars will be a further 40 minutes out of sync, causing the face of the planet to look as though it's revolving backwards. ●

> "When the planet isn't swathed in high volumes of Martian dust, the features that Mars has to offer are rewarding"

Mars seen through an amateur telescope



Path of Mars through 2014

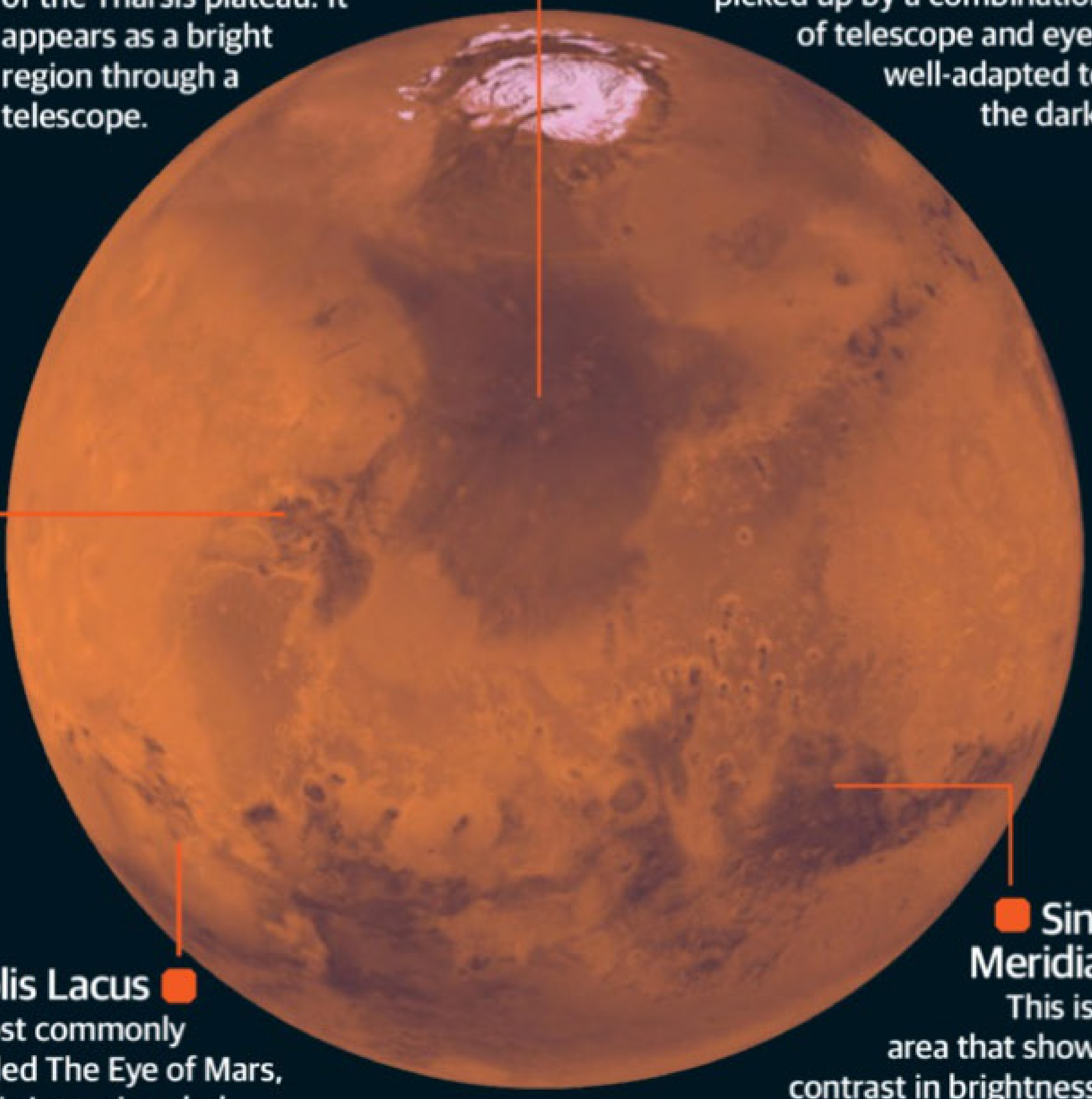
The path of the Red Planet throughout the year, where it will appear to move backwards – due to its movement relative to Earth – in a so-called retrograde motion.

At opposition
Mars will reach its brightest point in the sky on 8 April, hitting a magnitude of around -1.5 with 100 per cent of its face lit up.

Reverse motion
Mars started to change direction back in March. The planet will begin to change direction in the night sky again during May.

Entering Libra
The Red Planet will begin moving through the constellation Libra by August, decreasing in magnitude to around +0.5. However, 86 per cent of its surface will still be visible.

The features of Mars



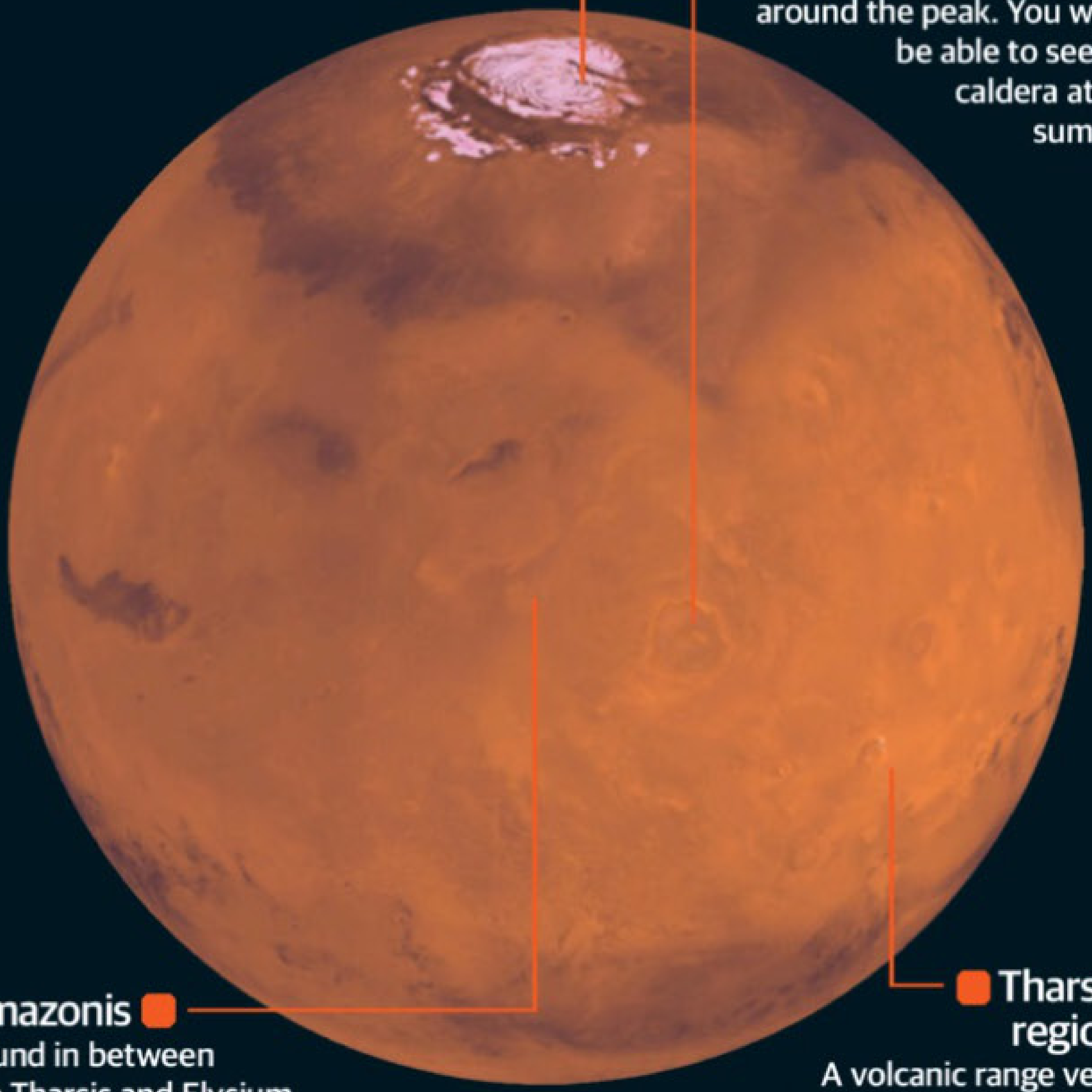
Chryse Planitia
A circular plain in the northern equatorial region of Mars, Chryse Planitia can be found to the east of the Tharsis plateau. It appears as a bright region through a telescope.

Mare Acidalium
The broadest and darkest feature visible on Mars, Mare Acidalium is a very prominent region that's easily picked up by a combination of telescope and eyes well-adapted to the dark.

Solis Lacus
Most commonly called The Eye of Mars, Solis Lacus is a dark feature on Mars that is frequently swamped by violent dust storms.

Sinus Meridiani
This is an area that shows a contrast in brightness or darkness, stretching from the east to the west. It has a diameter of around 1,622 kilometres (1,008 miles).

Mars at approximately 10pm (BST) on 8 April



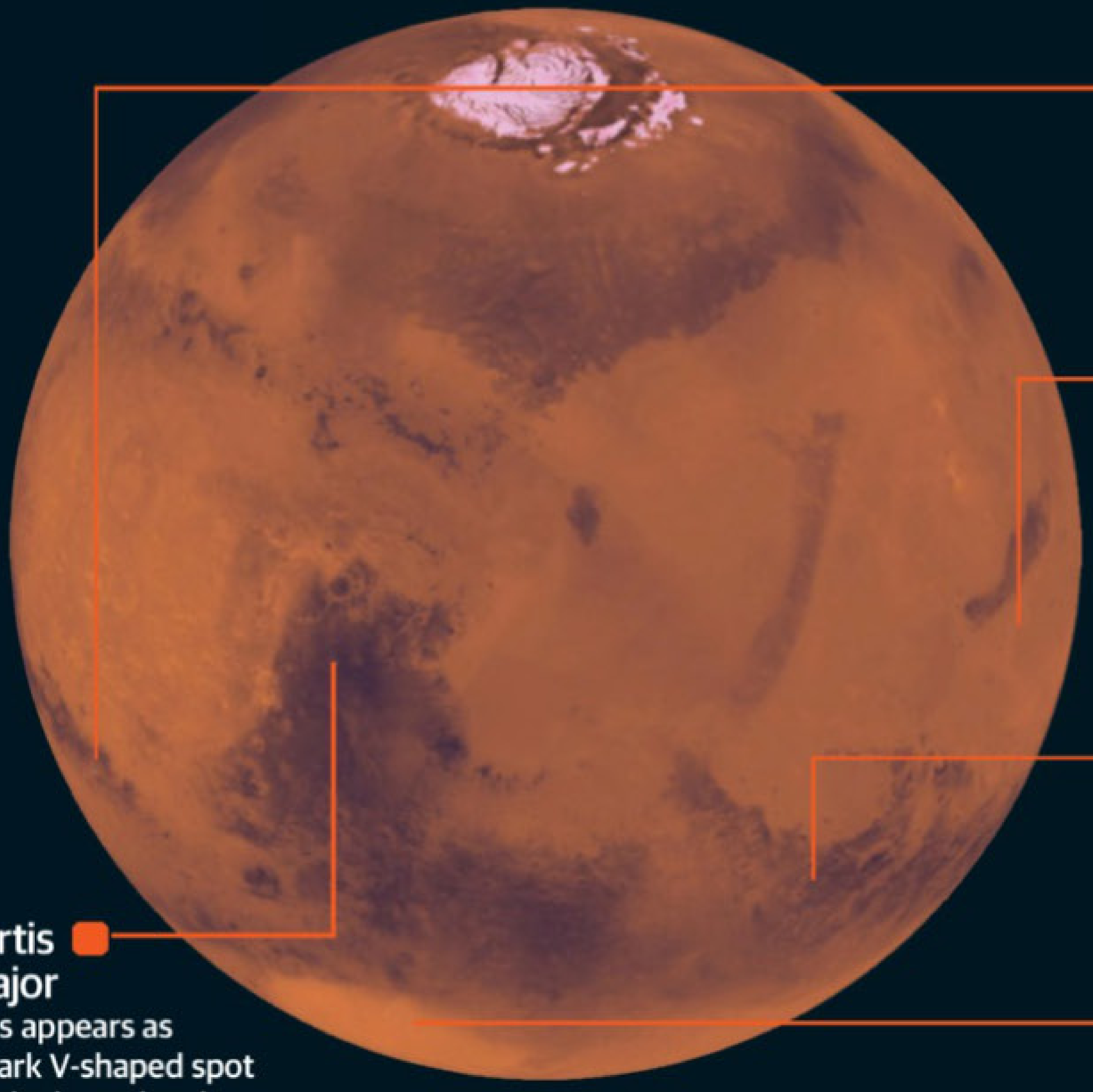
North polar cap
With it being summertime in the northern hemisphere on Mars, its usual water ice cap has shrunk back to reveal its core of carbon dioxide ice (also known as dry ice). The northern hemisphere is tilted towards us, however, making it easier to view.

Olympus Mons
Olympus Mons is hailed as the largest volcano in the Solar System at around 22.5 kilometres (14 miles) high. If you have a blue filter handy – and are patient – you might be able to spot Martian clouds around the peak. You won't be able to see the caldera at the summit.

Amazonis
Found in between the Tharsis and Elysium volcano ranges, this region is one of the smoothest plains on Mars, with a heap of classical light and dark features.

Tharsis region
A volcanic range very close to Olympus Mons consisting of three giant volcanoes Arsia, Pavonis and Ascraeus Mons.

Mars during the early hours of 9 April



Sinus Sabaeus
This dark finger, close to the equator, is near Meridiani Planum, a vast plain that contains Eagle crater, the landing site of NASA's Opportunity rover.

Elysium
This large, barren volcanic region near the planet's equator appears as a brighter patch through the telescopic eyepiece, which makes it more difficult to spot.

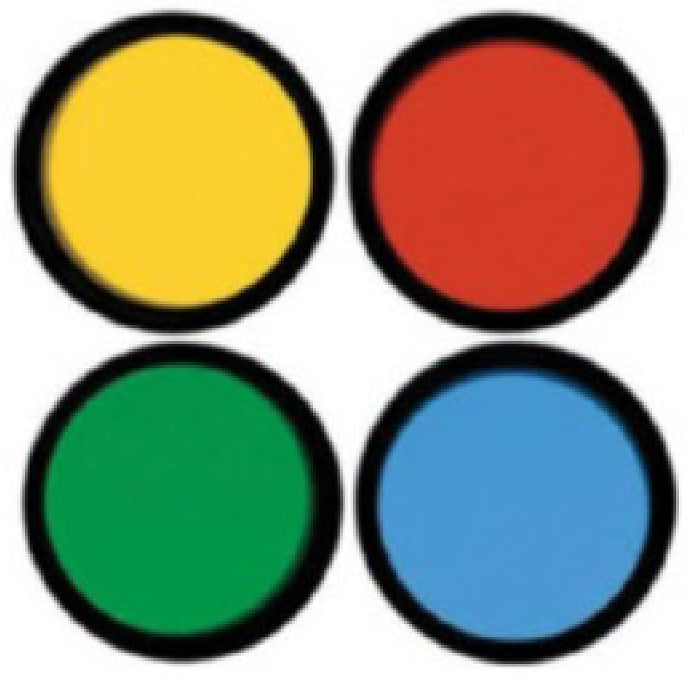
Mare Cimmerium
Part of the crater-filled southern highlands of the planet, Mare Cimmerium appears as another dark area through the telescope.

Syrtis Major
This appears as a dark V-shaped spot on the boundary between Mars' northern lowlands and southern highlands. It's the easiest marking to find on Mars' surface.

Hellas
A huge crater in the southern hemisphere that's 2,300 kilometres (1,429 miles) wide and appears as a bright spot in many telescopes – one of the most noticeable features on Mars.

Mars at approximately 10pm (BST) on 30 April

Filters and Martian features



Red: Use this filter for improving the definition of the darker and polar regions.

Deep yellow: This increases the contrast of Mars' polar caps, clouds as well as ice and dust storms that rage across the Red Planet.

Medium Blue: Use to enhance surface features, clouds as well as ice and storms on the surface.

Dark Green: Increases the contrast of ice and polar caps on Mars.

© NASA; Alamy

Me & my telescope

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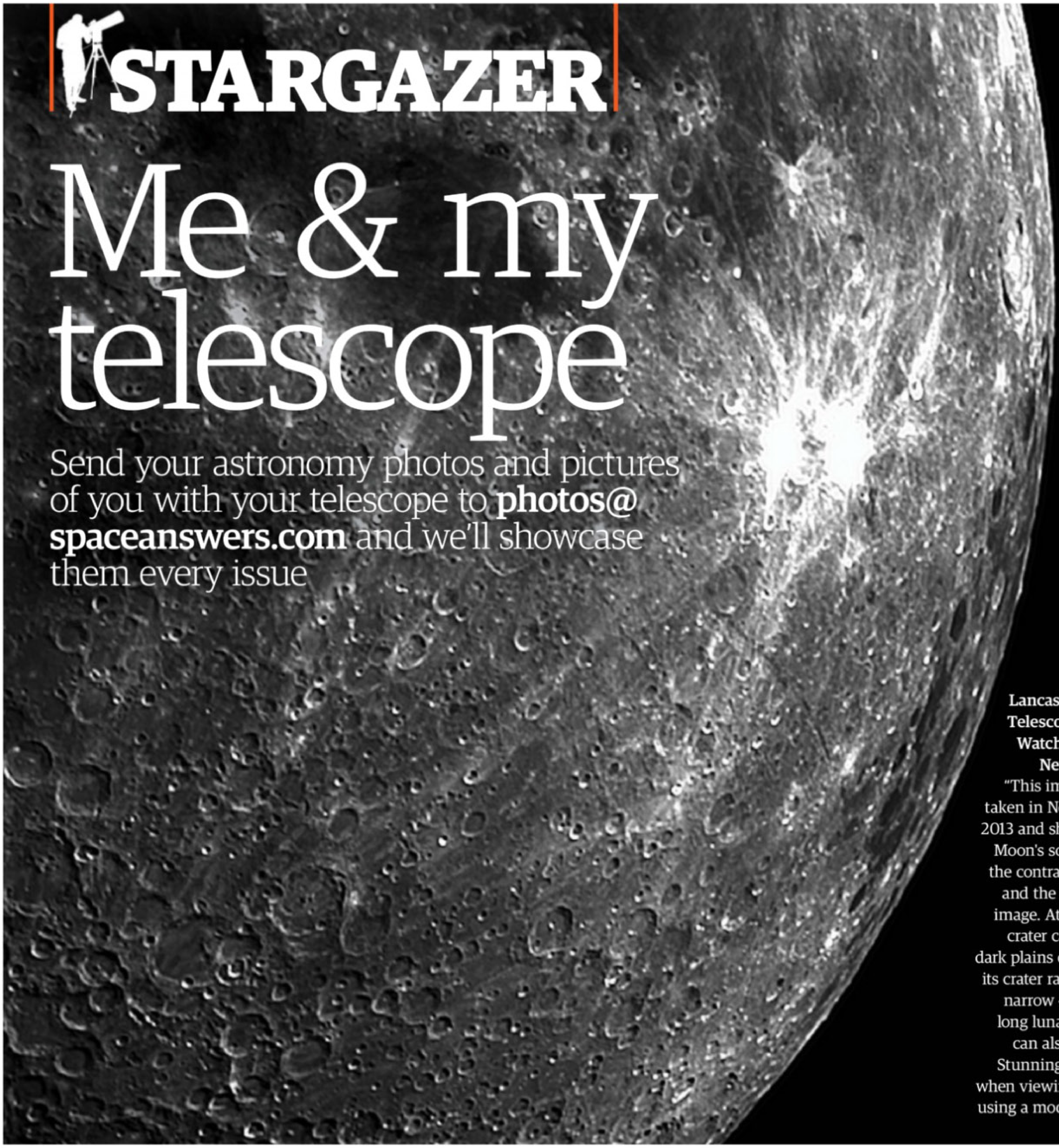


John Brady

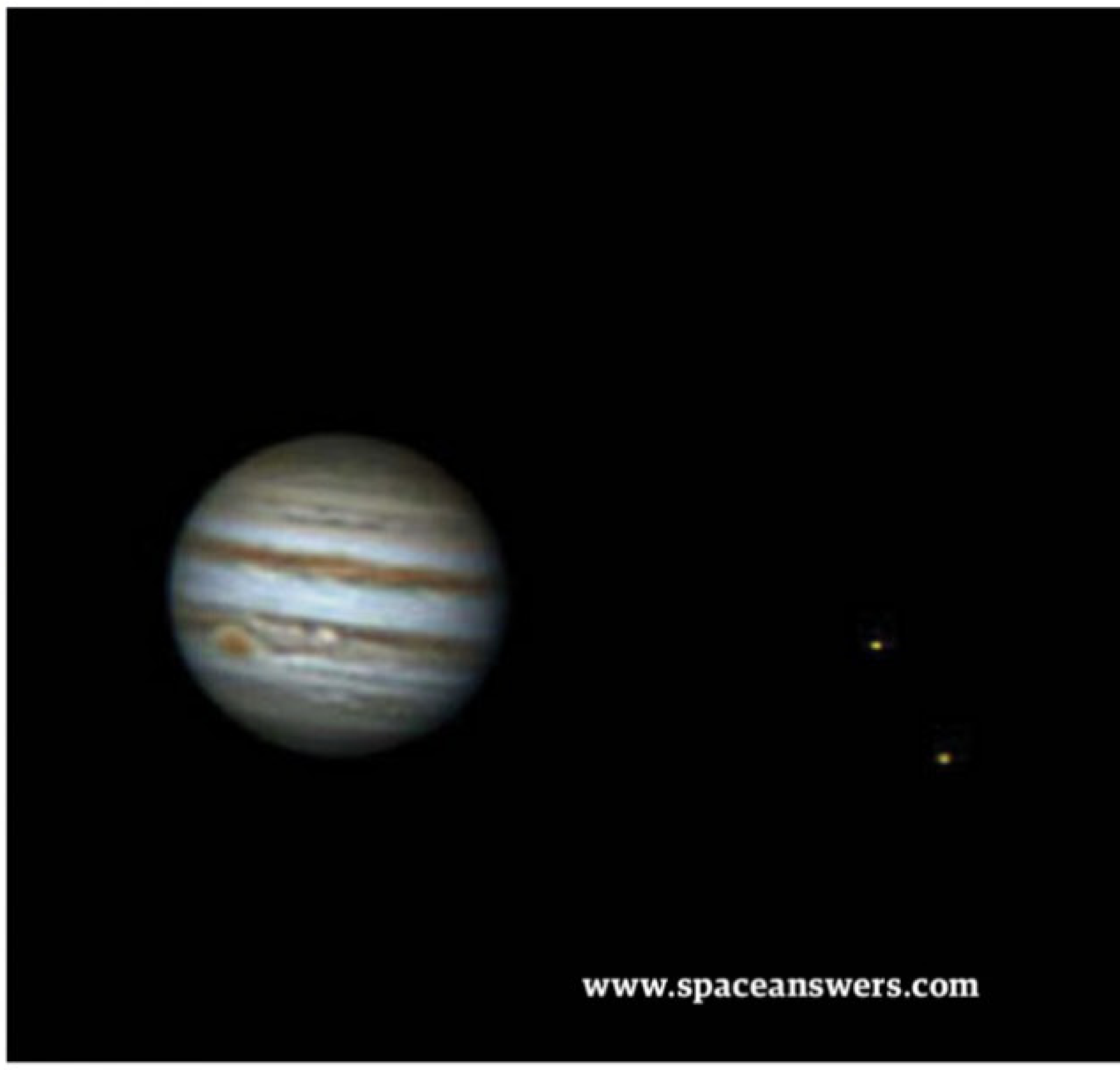
Lancashire, UK
Telescope: Sky-Watcher 200P Newtonian

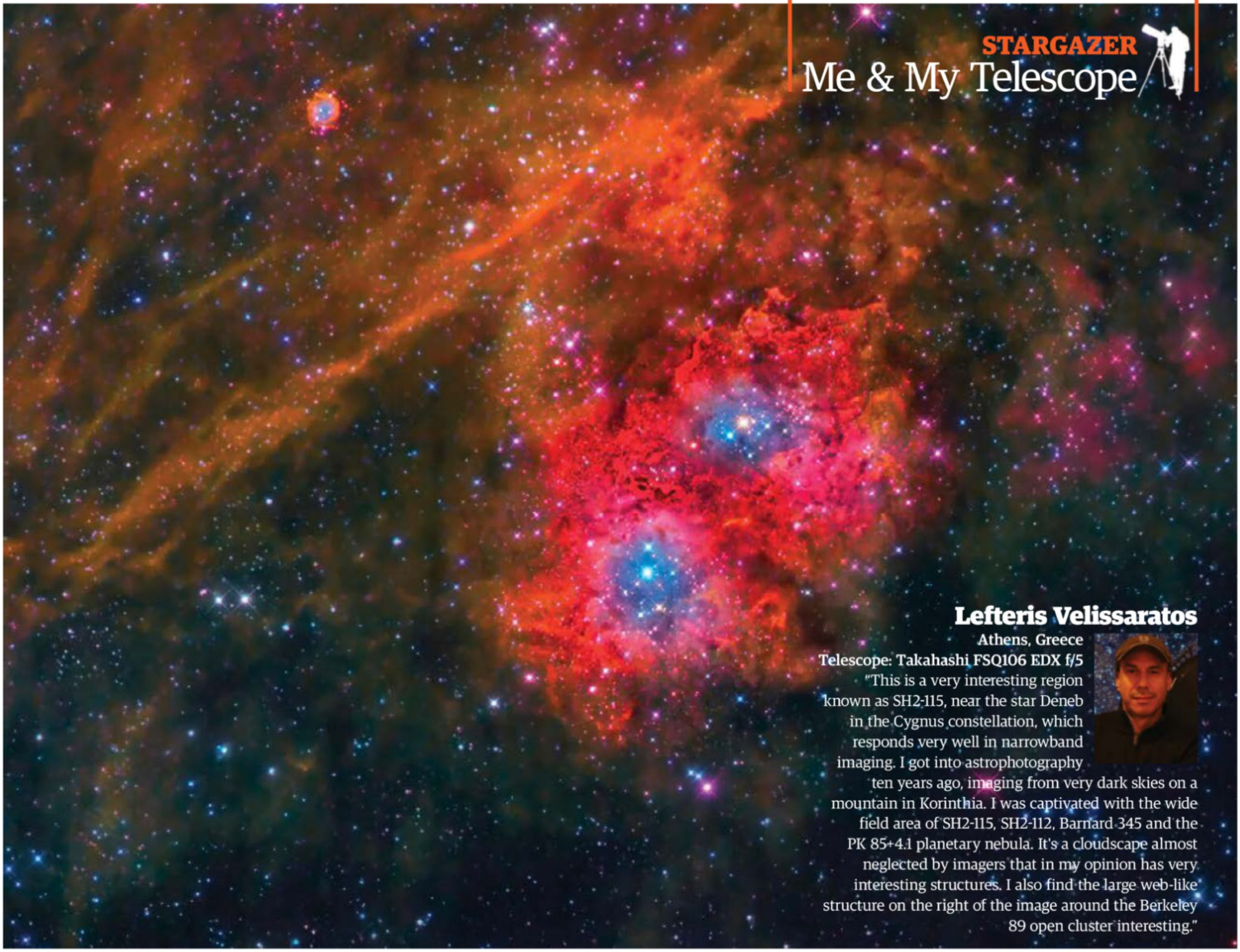
"This image was taken in November 2013 and shows the Moon's south-east area. I really like the contrast between the dark mare and the bright crater ejecta in this image. At top-centre, a single small crater can be seen set against the dark plains of the Mare Nectaris, with its crater ray heading north-east. The narrow 445-kilometre- (277-mile-) long lunar valley, the Vallis Rheita, can also be seen at middle-right. Stunning details can be teased out when viewing and imaging the Moon using a moderate-sized telescope and it never fails to impress."

Andy Li

West Sussex, UK
Telescope: 127mm Sky-Watcher Maksutov-Cassegrain

"I was bitten by the astronomy bug about 12 months ago when my wife bought me a telescope for Christmas. I took these images with a 127mm Sky-Watcher Maksutov-Cassegrain, which I have put onto a SkyProdigy Alt-Azimuth mount. The camera I used was a NexImage 1 that essentially is the same as a Philips SPC900NC webcam. I used a x2 Barlow lens for the larger image of Jupiter where the Great Red Spot is seen, as well as Io and Ganymede."





Lefteris Velissaratos

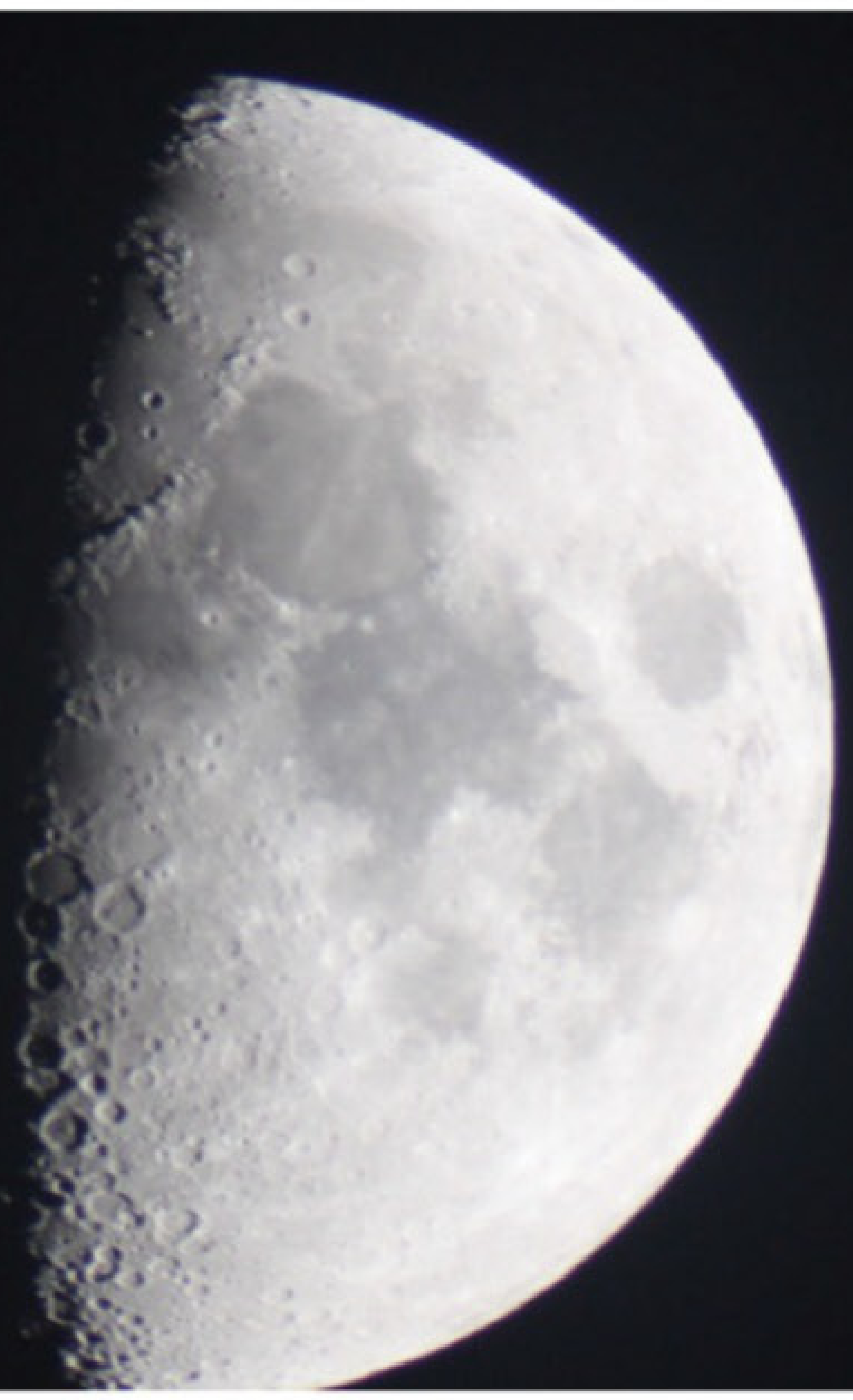
Athens, Greece
Telescope: Takahashi FSQ106 EDX f/5

"This is a very interesting region known as SH2-115, near the star Deneb in the Cygnus constellation, which responds very well in narrowband imaging. I got into astrophotography ten years ago, imaging from very dark skies on a mountain in Korinthia. I was captivated with the wide field area of SH2-115, SH2-112, Barnard 345 and the PK 85+4.1 planetary nebula. It's a cloudscape almost neglected by imagers that in my opinion has very interesting structures. I also find the large web-like structure on the right of the image around the Berkeley 89 open cluster interesting."

Isabel Richards

Stockport, UK
Telescope: 90mm refractor

"I am 15 years old and have always been interested in astronomy. I got my telescope about a year and a half ago. This photo of the Moon was taken using a DSLR camera and my telescope. I have never really done astrophotography before so this is quite new for me and I hope to take many more photos of various objects in space in the future. I never thought I would get such a clear picture so I am very pleased with this photo!"



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Stargazing stories

Email the story of how you got into astronomy to **photos@spaceanswers.com** for a chance to feature in **All About Space**

Gary Colville

Location: Baginton, Warwickshire, UK
Info: Astronomer for 33 years
Twitter: @astroforfun and @gazsc
Current rig
telescope: Skywatcher 130p
Mount: Skywatcher AZ GoTo
Other: Nikon DSLR D3000, Celestron Binoculars 15x70

"I became interested in astronomy at the age of seven when I saw something, I had no idea what it was then, but I now know it was Venus. But at seven it was a bright light that soon vanished; little did I realise, at seven years old, how the sky and the orbits work. That Christmas I got a telescope and I've been hooked ever since, although it has only been in the past ten years that I became more serious about it. I met astronomy friends on Facebook and in 2012 we formed the group Astronomy For Fun. We have done lots of outreach work.

"The best thing I've done in astronomy so far was this January's Stargazing Live event, being able to attend the live filming of the Wednesday night show. Due to the failure of Comet ISON - my fiancée Nancy was asked to take part in filming with another two people - filming was scrapped, so we were invited as guests.

"The following Saturday, we held our own Stargazing Live event. We had over 740 people turn up. Being able to show the general public why I love astronomy, [as well as] what we do as a group, is unbelievable. I tend to observe from my back garden, but I am lucky to have a Lunt Roman Fort in the village that the group has managed to get access to and has monthly meets at." ■

> "Little did I realise, at seven, how the sky and orbits work"

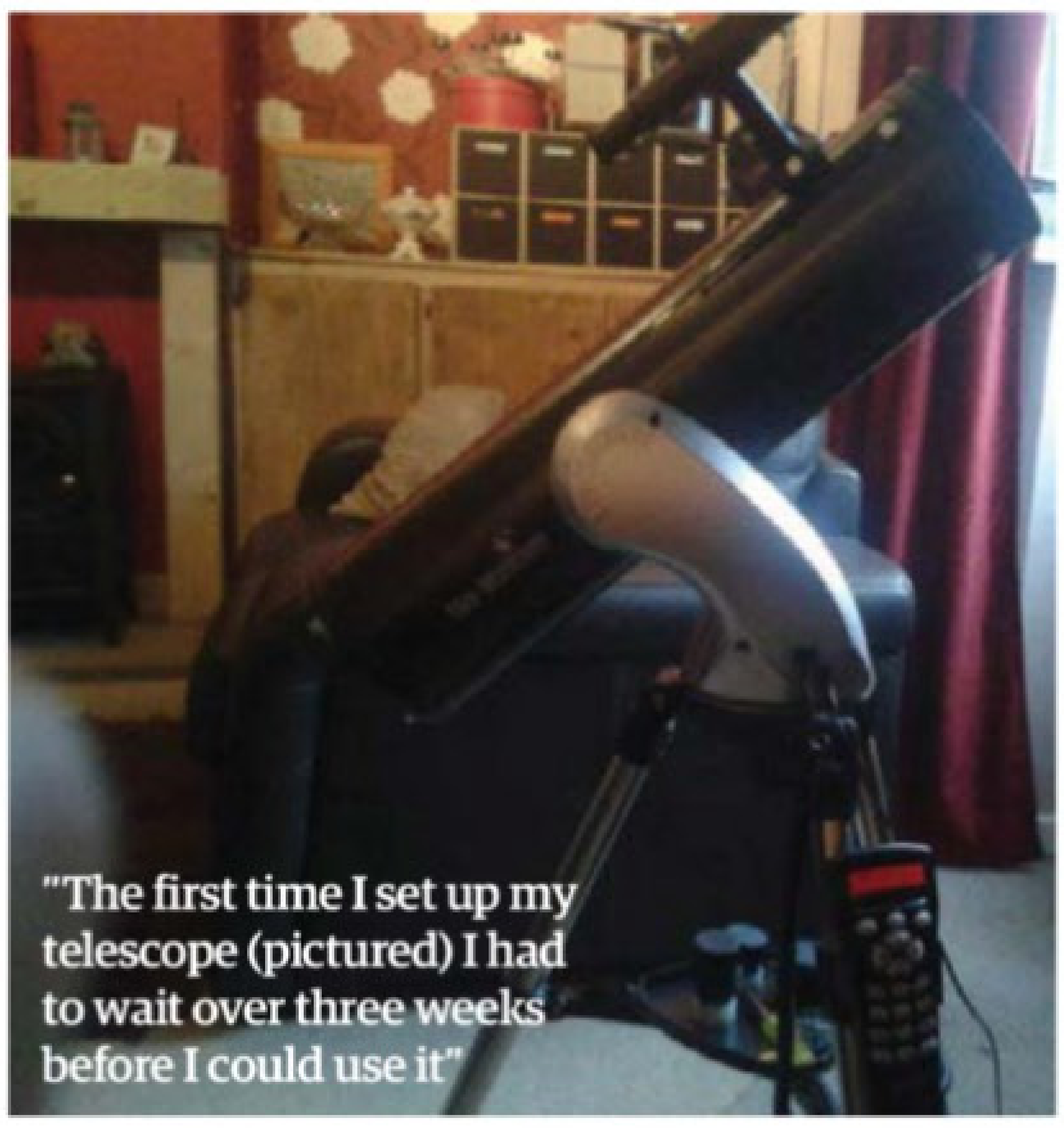
Gary's top three tips

1. Join a group
Get involved with local groups, don't be afraid to ask questions and enjoy getting the help. Ask to view through their telescopes before buying your own.

2. Study the sky
Learn the night sky with the naked eye, get to know the basic constellations and learn where planets are. The rest will follow in time, it just takes practise.

3. Observe the Moon
The easiest viewing target is the Moon. Through any telescope it's a sight I enjoy to look at. Some study deep space, and you have a lot of options, but try to start off easy.

"Here you can see how using a stacking programme affects the image"



"The first time I set up my telescope (pictured) I had to wait over three weeks before I could use it"

"This is me receiving my NASA Night Sky Award via the Charlie Bates Solar Astronomy Project over Live Link"

"I love this image as it's showing some Earth shine and clear details"

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“This is a shot of my daughter and I in Shohola Falls, Pennsylvania. I used to drive around in my RV and set up at dark sites”

Ike Rodriguez

Location: New York City, USA
Website: www.flickr.com/photos/111197448@N08
Info: Astronomer for over a year
Current rig
telescopes: Celestron 8" Edge
Mount: AVX Mount
Other: MallinCam Xtreme CCD video camera

“I first got into astronomy during a weekend meditation retreat. My friend had a toy 60mm scope that I just decided to point at the Moon. I was amazed at what I saw with that small scope on a rickety mount.

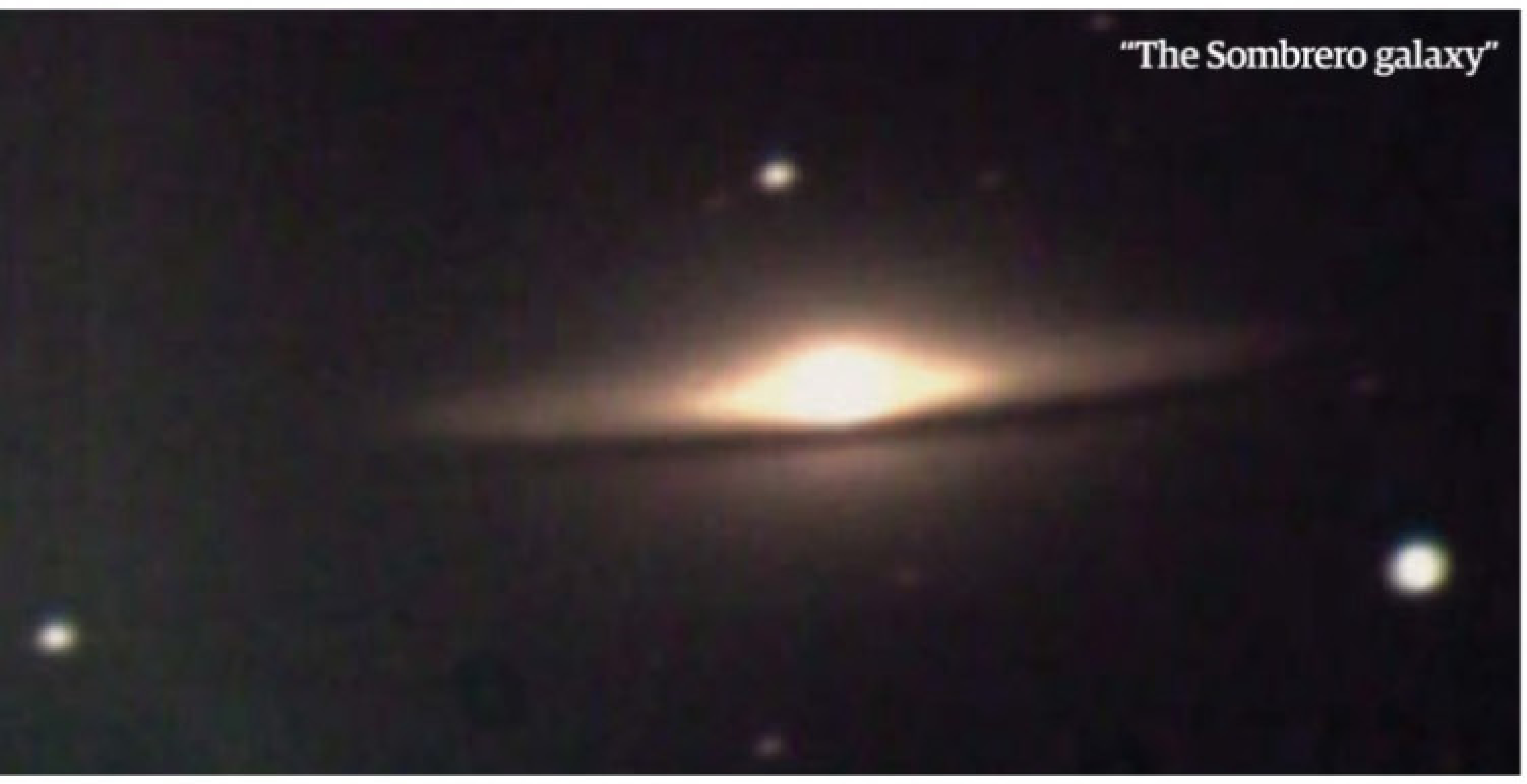
“On my 39th birthday I decided that I would buy myself a scope. I bought a $150 Celestron Powerseeker 127 with a manual equatorial mount. From the rooftop of my New York City apartment I didn't see the Moon out, so I decided to point the scope at a really bright star to the east. I could not believe my eyes – I was looking at Jupiter. Then I decided to point at the Great Orion nebula that we see so many colourful photos of. To my surprise there was no colour. I looked at the box wondering if I had to specify monochrome or colour when I bought the scope. I laugh about it now.

“This started the journey that most astrophotographers are on. We are chasing the image, we do whatever it takes and spend whatever we must to capture that image, to just simply share. There is no financial gain or fame – it's just the simple human act of sharing that drives me and most astrophotographers I know. I'm so dedicated that my girlfriend had to accept it so we named the scope Stella and I call her my 'other wife' with her own house (the observatory). It makes for a good laugh.

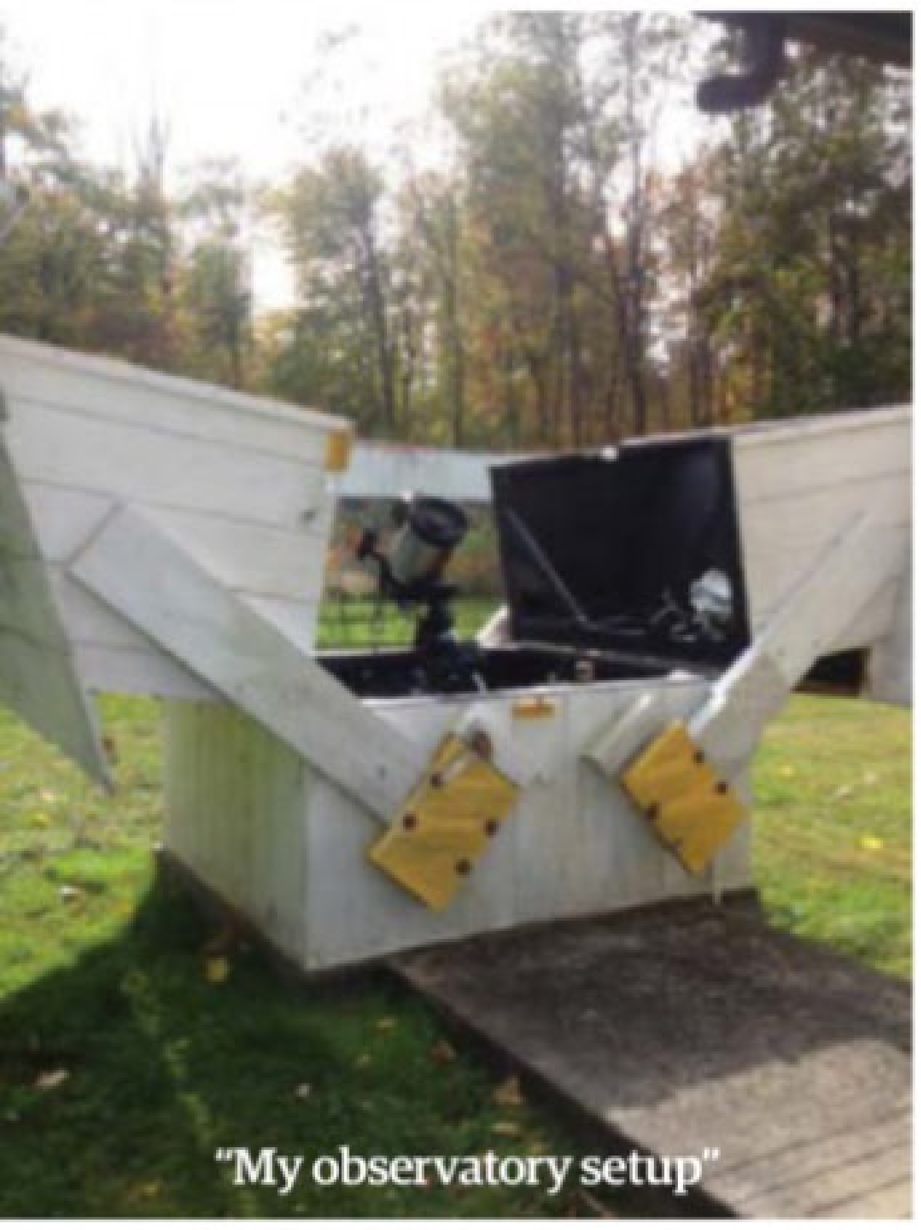
“After much research and knowing that I don't want to spend hours on a computer processing photos, I made the move to buy a MallinCam Xtreme CCD video camera. With the Miloslick control program it enables me to process my images in real-time: exposures, stacking, histogram, dark frames and so on, all on the fly.

“I can share my images in real-time from the field or even online through **www.nightskiesnetwork.com** where I go by Spiritseeker Observatory. My friend from the Rockland Astronomy Club gave me full use of his unused homemade observatory so I could be permanently mounted and achieve precise polar alignment along with TPoint from Software Bisque. I'm able to land targets dead-centre and have enjoyable sessions, most times from the comfort of my home.” ■

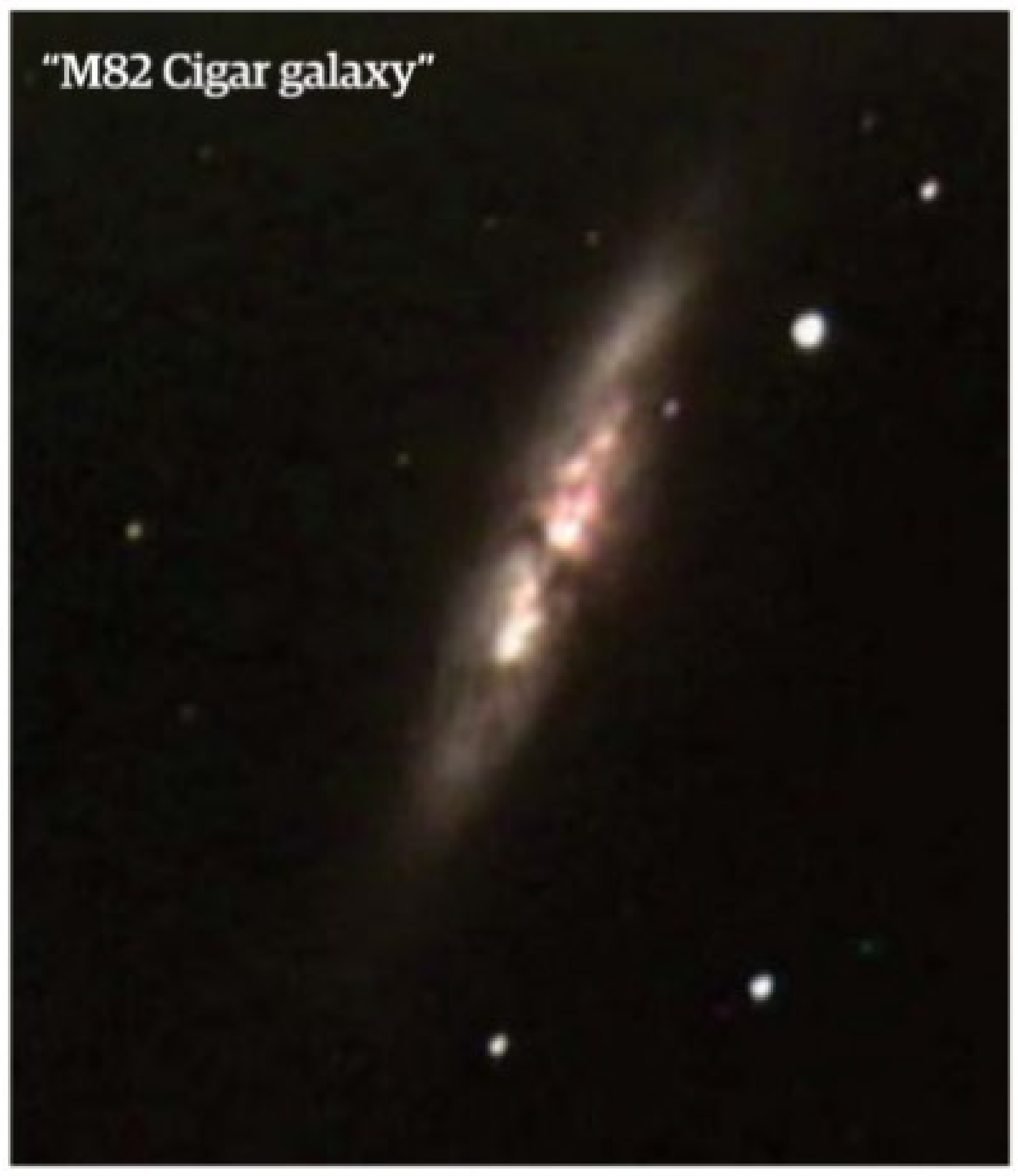
> “We are chasing the image, we do whatever it takes and spend whatever we must to capture that image”



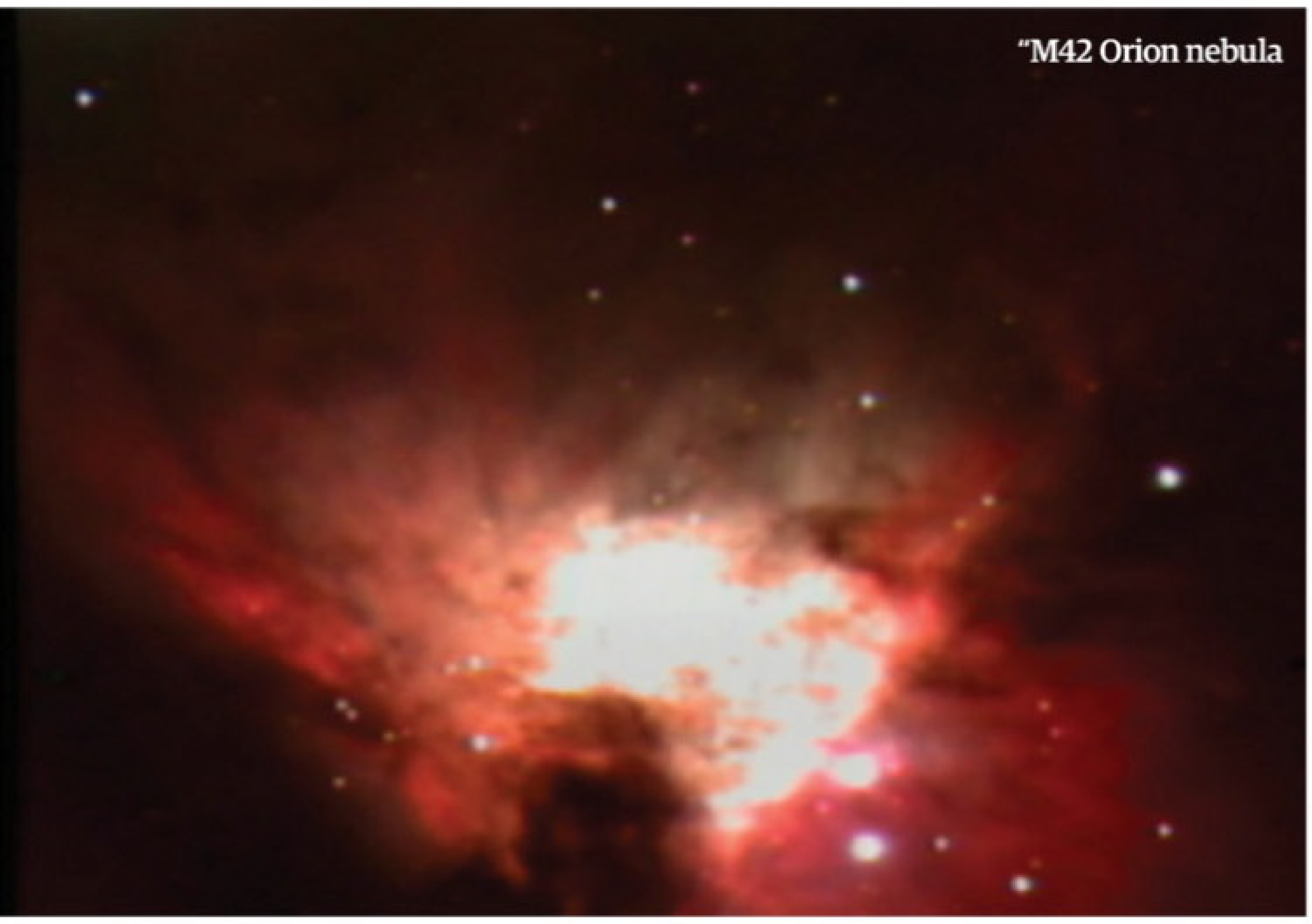
“The Sombrero galaxy”



“My observatory setup”



“M82 Cigar galaxy”



“M42 Orion nebula

“The Stargate Cluster”

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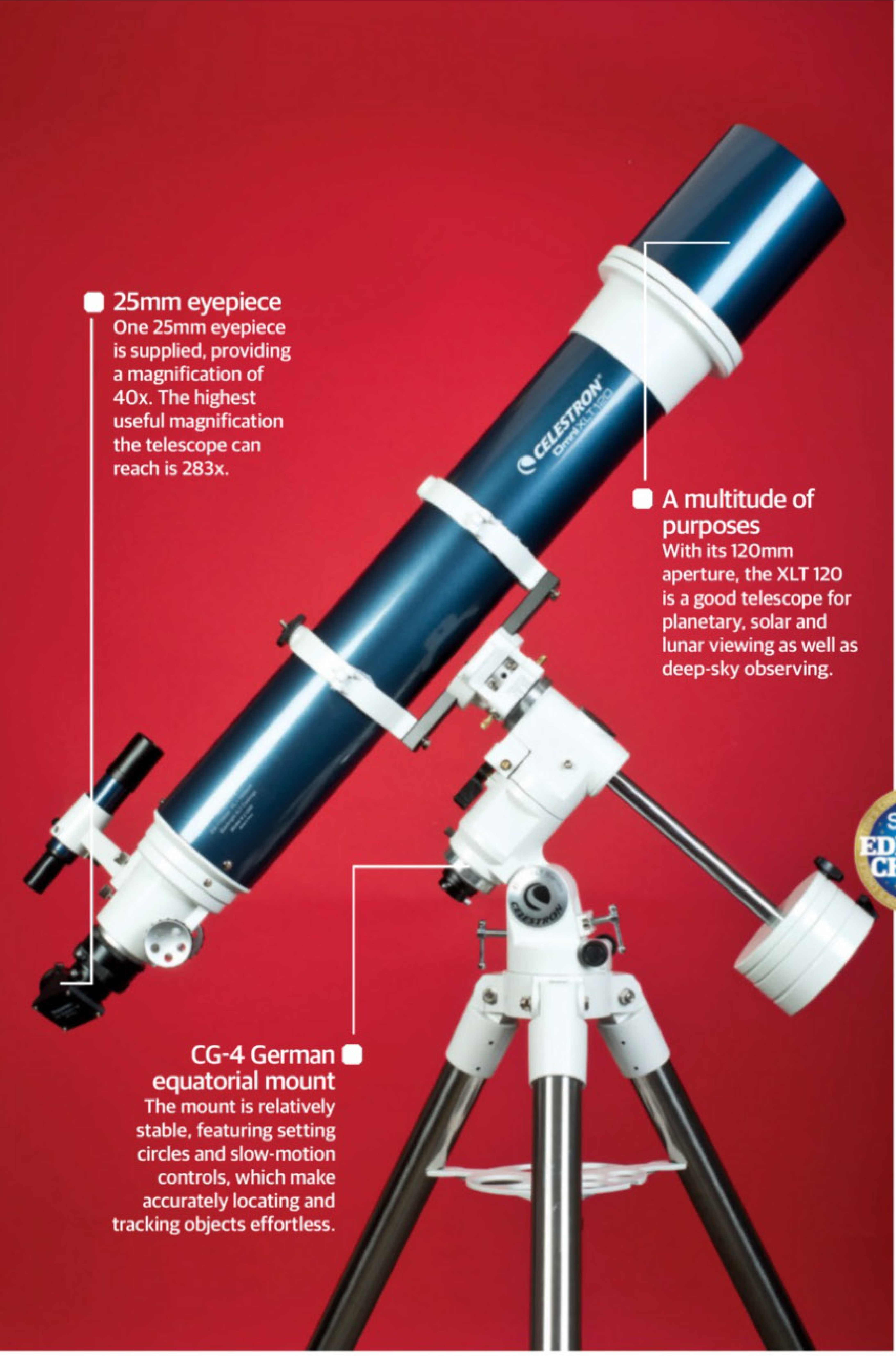
Celestron Omni XLT 120

With impressive optics for the cost, the XLT 120 refractor is the perfect upgrade from your entry-level telescope



25mm eyepiece
One 25mm eyepiece is supplied, providing a magnification of 40x. The highest useful magnification the telescope can reach is 283x.

A multitude of purposes
With its 120mm aperture, the XLT 120 is a good telescope for planetary, solar and lunar viewing as well as deep-sky observing.

CG-4 German equatorial mount
The mount is relatively stable, featuring setting circles and slow-motion controls, which make accurately locating and tracking objects effortless.

The XLT 120's optics are excellent, made from the finest optical glass with aspheric shaping technology, to limit spherical aberration, as well as StarBright XLT coating

The XLT 120 is a fine telescope at a reasonable price and, despite sporting counterweights for balance, can be moved fairly easily

Telescope advice

Cost: £520 / $1,017.95
From: www.hama.co.uk
Type: Refractor
Aperture: 120mm
Focal length: 1,000mm

The XLT 120 was a breeze to set up and, with the 3.2- and 1.8-kilogram weights combined with the tube, mount and stainless-steel tripod for an overall weight of 29.03 kilograms, it isn't too heavy.

The overall build of the telescope is excellent for the price, featuring a solid base that's sturdy and suitable for both observing and astrophotography. It's worth noting that the XLT 120 is not an entry-level telescope but serves as more of an upgrade to a basic instrument. A 25mm eyepiece and software database of night-sky objects is also included.

The incredibly impressive optics offered up beautifully clear and sharp views of the Moon's features, as well as Jupiter and its prominent satellites. Thanks to its StarBright XLT coating, this refractor gathers more light and features aspheric shaping technology to limit spherical aberration.

The telescope is also capable of solar viewing combined with the appropriate filters and provides decent views of deep-sky objects, including star clusters.

The XLT 120 has a few minor drawbacks: a very stiff focuser, a somewhat flimsy Right Ascension circle and chromatic aberration. This means bright Solar System objects could be seen to have purple or blue fringing to their limbs. ●

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1 Kit
Celestron Eye Piece & Filter Kit

Cost: £185 / $159.95

From: www.hama.co.uk

Featuring a great selection of eyepieces and filters for getting the most out of viewing, the Celestron Eye Piece & Filter Kit is perfect for anyone new to amateur astronomy.

The selection of Superior Grade Plössls includes a 6mm, 8mm, 13mm, 17mm and 32mm, all of which work brilliantly with any 1.25" eyepiece-compatible telescope. All are fully multi-coated, with the 6mm, 8mm and 13mm (for poor viewing conditions), providing great planetary and lunar views with good eye relief.

The 13mm, 17mm and 32mm are best for deep-sky objects, since they give a good field of view. A 2x Barlow lens was also supplied, enabling us to give one eyepiece double the magnification and improved views.

Coloured filters suitable for planetary and lunar viewing are also included in the package, providing even more options.

2 Binoculars
Oregon Observation 15x70

Cost: £99 / $N/A

From: www.tringastro.co.uk

The Oregon Observation binoculars are surprisingly light and easy to hold, featuring a slim-line ZCF body style in protective rubber armour. If you wish, the binoculars can also be easily attached to a tripod.

Using the 70mm objectives combined with the BAK-4 prism multicoated optical system, we immediately turned our attention to the Orion nebula and were delighted to see a crisp and clear image with a couple of the nebula's Trapezium star cluster's brightest members.

Craters and maria on a waxing gibbous Moon were both impressive, as was picking out three of Jupiter's most prominent moons and the gas giant itself, which appeared as a white disk. Sadly, we experienced purple or red fringing when looking at bright objects, meaning that these binoculars aren't best for bright, high-contrast Solar System targets.

3 Book
X-15

Cost: £25 / $30

From: www.zenithpress.com

If you're into aviation, then you'll love this glossy hardback book that focuses on nine years of the North-American X-15, a rocket-powered aircraft jointly operated by the United States Air Force and NASA. Smaller than a tome that you're likely to find on a coffee table, it isn't the full history of the first space plane, but if you want an introduction to this fascinating aircraft and the first pilots of the Cold War space race, this is certainly for you.

X-15: The World's Fastest Rocket Plane and the Pilots Who Ushered in the Space Age is authored by John Anderson, the curator of aerodynamics at the Smithsonian National Air and Space Museum, alongside Richard Passman, the chief aerodynamicist for the Bell X-2 – the first plane to fly faster than Mach 3. The book is expertly written and beautifully illustrated throughout its 144 pages and is a must-read from the Smithsonian series.

4 Star tracker
Vixen Polarie

Cost: £379 / $399

From: www.astronomia.co.uk

The Vixen Polarie Star Tracker looks just like an attractive compact camera, but there's definitely much more to it, especially if you're interested in getting great shots of the night sky.

Picking the Polarie up, we expected a weight similar to a DSLR camera, but amazingly it's quite hefty, ticking the boxes when it comes to robust build and durability. What's more, the Star Tracker can either be powered by a couple of AA batteries or give you the option to connect a 5V DC power supply using a USB socket.

Giving the Polarie a try, we found it worked very well and was easy to set up and attach to a camera. It was able to take images, tracking the stars in such a way that you can shoot constellations and the Milky Way without star trails being recorded.

One drawback is that it manages to exhaust batteries quickly if you're observing on a very cold night, so make sure you bring spares.

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To be in with a chance of winning, all you have to do is answer this question:

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A: Satellite B: Asteroid C: Star

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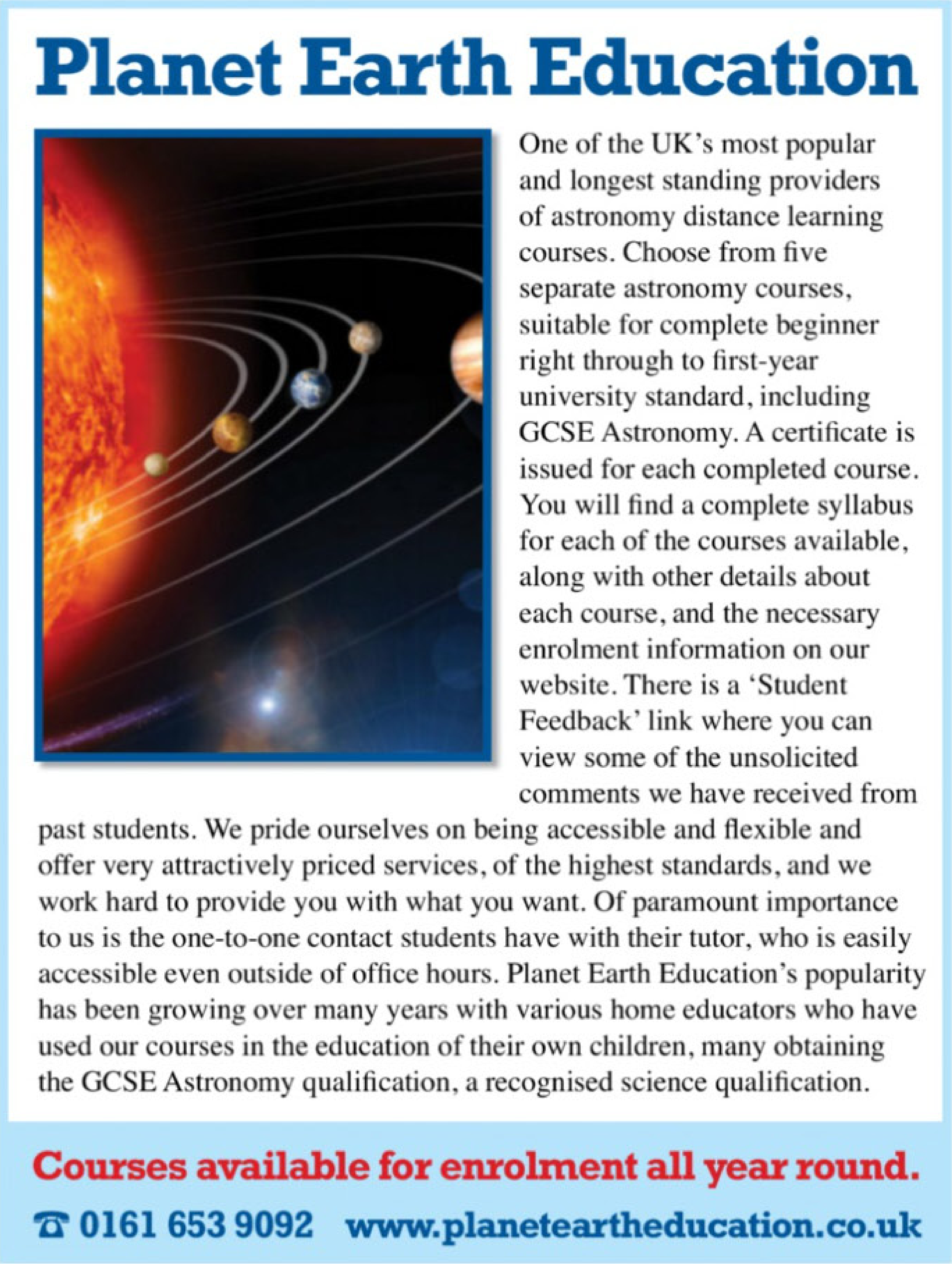
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Thanks to Leavitt we now know that our Milky Way is just one of hundreds of billions of galaxies in the universe

Henrietta Leavitt

The unsung astronomer who helped to discover our place in the universe

When discussing the history of astronomy there are a number of famous names that instantly spring to mind: Hubble, Herschel, Galileo and others. They all contributed so much to astronomy, but there are many other names that go unrecognised, often unappreciated for their contributions. Perhaps there is none more so, at least with regards to her impact on astronomy, than Henrietta Swan Leavitt. Where others in her time debated over our true place in the universe, her calculations paved the way to some of the most important discoveries of the 20th century that answered that very question.

Leavitt was born on 4 July 1868 in Lancaster, Massachusetts, US. She was the daughter of a congregational minister and in her youth attended Oberlin College and the Society for Collegiate Instruction of Women (later Radcliffe College), the latter of which she graduated from with a bachelor's degree in 1892. In the last year of college she took a course in astronomy that she studied with great enthusiasm. It was also around this time that she suffered a serious illness that left her severely deaf, but her love for astronomy remained.

The late 19th and early 20th centuries, however, were not an enjoyable time for female astronomers. Women weren't allowed to operate telescopes and instead often found themselves performing somewhat mundane tasks for men. In 1893 Leavitt began working at the Harvard College Observatory under American astronomer Edward Pickering. She was part of a group of skilled, highly educated women employed by Pickering for a pittance of about 30 cents an hour to sift through mountains of astronomical data.

Each woman was given a different set of data to catalogue and analyse. Leavitt was assigned to study variable stars, those whose luminosity varied over time but whose exact workings were poorly understood. In her studies she found thousands of variable stars in the Magellanic Clouds and noticed that the brighter a variable star was, the longer its period of variability. She published her results in 1908 in the *Annals of Harvard College Observatory*.

The stars she focused on were so-called Cepheid variables, a class of very luminous variable stars. She was the first to notice this strong correlation between their luminosity and their period of pulsation. Using the assumption that these stars were all at a similar distance from Earth in the Magellanic Cloud, she calculated the period-luminosity relationship of the stars.

This discovery had huge repercussions for astronomy as a whole. The period-luminosity relationship enabled Cepheids to be used as standard candles, or in other words distance markers. They were incredibly useful for working out the distances to objects that were too far to be calculated by other methods. In the 1920s astronomer Edwin Hubble detected Leavitt's Cepheid variables in Andromeda and was able to conclude that it was another galaxy rather than a part of the Milky Way, placing us in just one of hundreds of billions of galaxies. Similarly, astronomer Harlow Shapley used Cepheid variables to deduce that our Sun was not at the centre of the galaxy, but rather in the outer regions. Leavitt's discovery turned astronomy on its head and for the first time enabled astronomers to begin working out just where we fit into the universe.

Leavitt went largely unrecognised for her work and in 1921 died of cancer. In 1925 a Swedish mathematician, Gösta Mittag-Leffler, attempted to nominate Leavitt for a Nobel Prize, only to discover she had died four years earlier. Nonetheless, the influence of her work remains plain to see and it is thanks to her dogged determination that we now have a greater understanding of the universe than ever before. Perhaps now, when discussing important names that have significantly contributed to astronomy, Henrietta Leavitt should be one of the first on the list. ■

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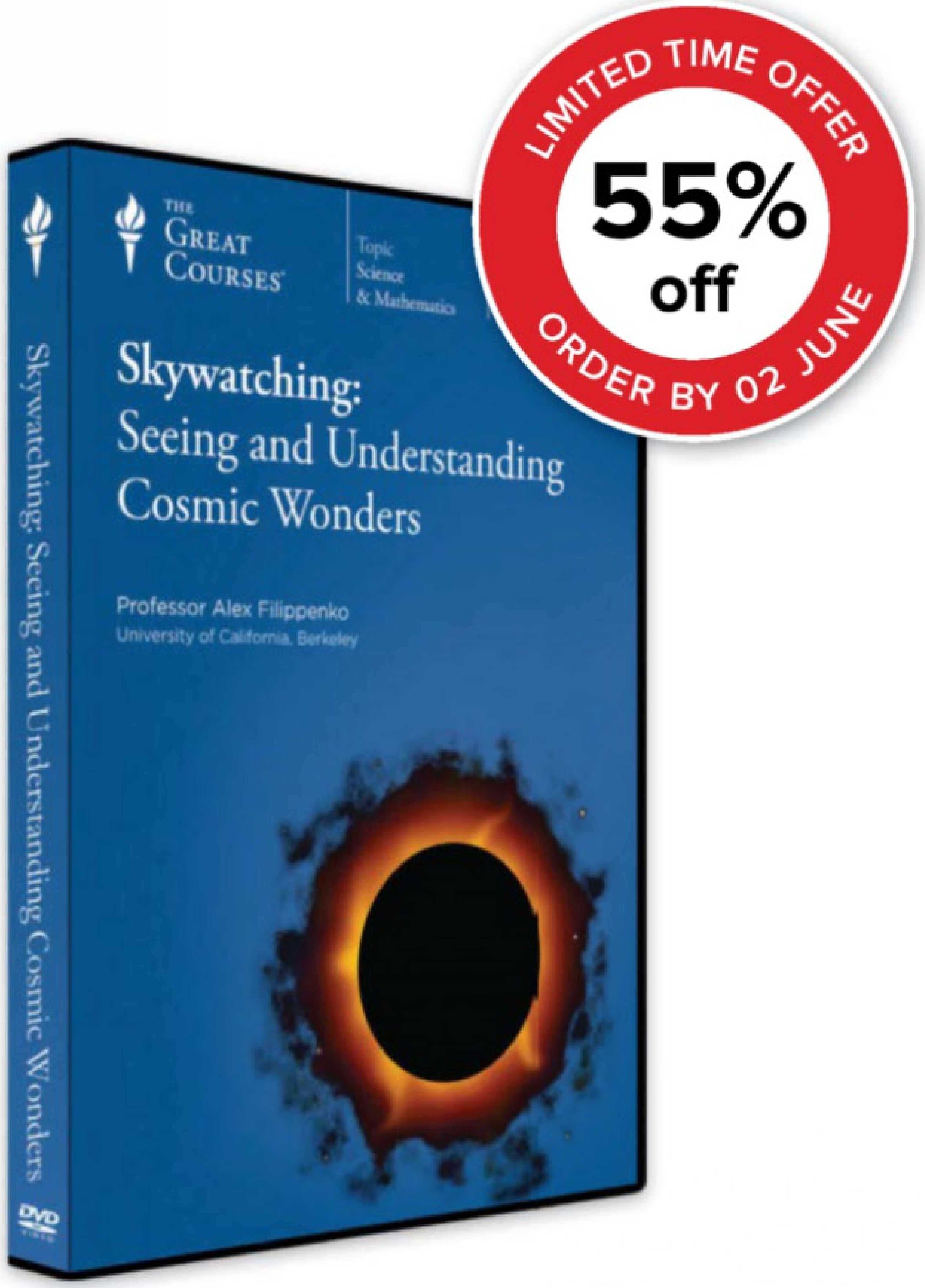
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